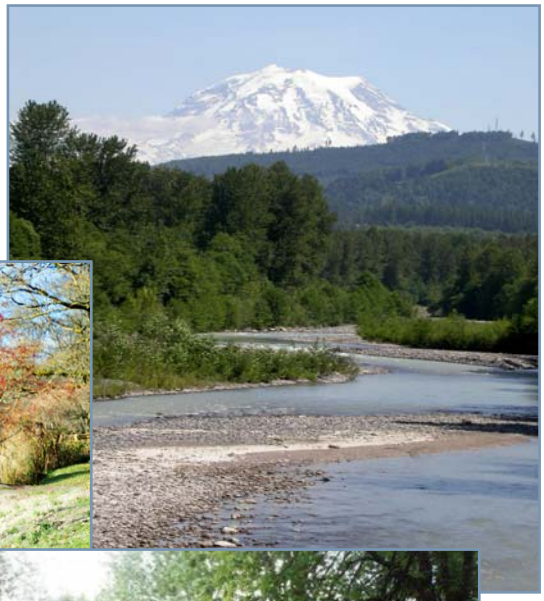
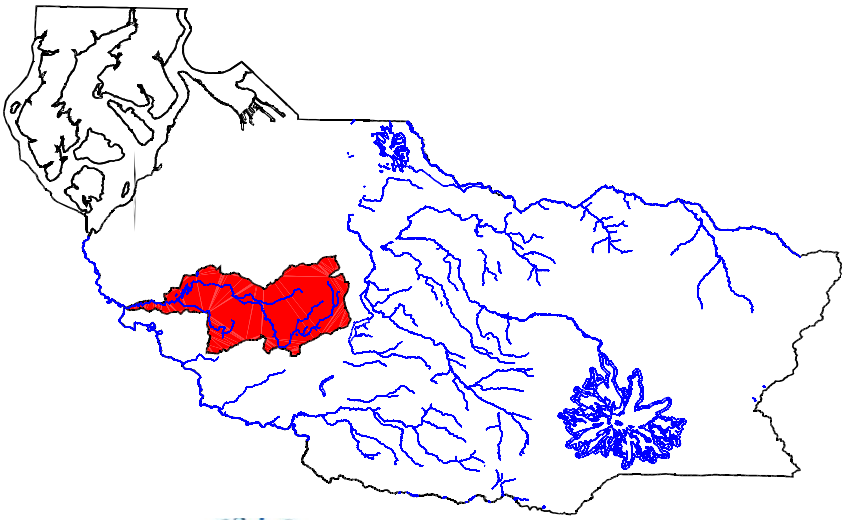
Muck Creek Basin Plan

Volume 1 - Basin Plan & SEIS

MUCK CREEK BASIN PLAN
Volume 1 – Basin Plan & SEIS

As Adopted PCC 2003-62s
September 2005





Pierce County
Public Works & Utilities
Water Programs Division

FILE NO. 21-A PROPOSAL NO. 2003-62s

Sponsored by: Councilmember Shawn Bunney

Requested by: County Executive/Public Works & Utilities Dept.

ORDINANCE NO. 2003-62s

AN ORDINANCE OF THE PIERCE COUNTY COUNCIL AMENDING CHAPTER 19D.60 OF THE PIERCE COUNTY CODE, "STORM DRAINAGE AND SURFACE WATER MANAGEMENT PLAN"; ADOPTING THE "MUCK CREEK BASIN PLAN" FOR THE UNINCORPORATED AREA OF PIERCE COUNTY, AS AN AREA UPDATE TO PIERCE COUNTY'S STORM DRAINAGE AND SURFACE WATER MANAGEMENT PLAN; AND ADOPTING FINDINGS OF FACT AND CONCLUSIONS.

WHEREAS, The Pierce County Council adopted Ordinance No. 87-205 on March 15, 1988, which was amended by County Ordinance No. 88-200 on December 20, 1988, thereby establishing Pierce County Storm Drainage and Surface Water Management; and

WHEREAS, The Pierce County Council adopted Ordinance No. 91-113 on November 5, 1991, which adopted the "Pierce County Storm Drainage and Surface Water Management Plan" (Master Plan), codified as Chapter 19D of the Pierce County Code (PCC) for the unincorporated areas of Pierce County; and

WHEREAS, The Master Plan focused on Countywide flood hazard reduction with a relatively minor emphasis on the Muck Creek Basin as one of 26 County basins; and

WHEREAS, The focus of the Master Plan within the Muck Creek Basin was almost exclusively on flood hazard reduction, with minimal regard to water quality and/or associated riparian habitat; and

WHEREAS, Significant population growth and incorporations have occurred within Pierce County since adoption of the Master Plan; and

WHEREAS, The Council adopted the Pierce County Comprehensive Plan several years after it adopted the Master Plan; and

WHEREAS, Since the adoption of the Master Plan, Pierce County has been issued a National Pollutant Discharge Elimination System (NPDES) stormwater permit under the federal Clean Water Act which imposes numerous requirements and standards on the County; and

WHEREAS, Chinook Salmon and Bull Trout which exist in Pierce County waters have been listed as endangered species since adoption of the Master Plan; and

WHEREAS, Pierce County participates in the Federal Flood Insurance Program for reduced flood insurance for County residents and receives additional benefits as a Federal Emergency Management (FEMA) Community Rating System participant, which favors comprehensive surface water management plans; and

WHEREAS, The Pierce County Council has received the Findings of Fact, Staff Report, and recommendation for approval of the Muck Creek Basin Plan and the Final Supplemental Environmental Impact Statement from the Pierce County Planning Commission; and

WHEREAS, Proper notice has been given of a public hearing held on the 13th day of September, 2005, and it is in the best interest of Pierce County and its citizens that the Muck Creek Basin Plan be adopted for the unincorporated area of Muck Creek Basin, Pierce County; NOW, THEREFORE,

BE IT ORDAINED by the Pierce County Council:

Section 1. Chapter 19D.60 PCC is hereby amended as set forth in Exhibit "A" which is attached hereto and incorporated herein by reference, to include the "Muck Creek Basin Plan" and to make other technical revisions.

Section 2. The Pierce County Council hereby adopts the "Muck Creek Basin Plan" dated April 2003 as set forth in Exhibit "B" which is attached hereto and incorporated herein by this reference.

Section 3. The Pierce County Council hereby adopts Findings of Fact and Conclusions as set forth in Exhibit "C" which is attached hereto and incorporated herein by reference.

PASSED this 13th day of September, 2005.

ATTEST:

Denise D. Johnson
Clerk of the Council

PIERCE COUNTY COUNCIL
PIERCE COUNTY, Washington

Shawn Bunney
Council Chair

PIERCE COUNTY EXECUTIVE

John W. Ladenburg
Approved ✓ Vetoed ____
this 16 day of Sept, 2005.

Date of Publication of
Notice of Public Hearing: August 24, 2005

Effective Date of Ordinance: September 26, 2005

EXHIBIT "A" TO ORDINANCE NO. 2003-62s

Chapter 19D.60

STORM DRAINAGE AND SURFACE WATER MANAGEMENT PLAN

(Ord. 2001-63s2 § 2 (part), 2001; Ord. 97-87S2 § 6 (part), 1997; Ord. 96-111 §§ 2, 8, (part) 1996)

The following documents are hereby incorporated by reference to this Plan:

A. Pierce County Storm Drainage and Surface Water Management Plan, James M. Montgomery Consulting Engineers, Inc., March 1991, and area updates, including Clover Creek Basin Plan, Pierce County Water Programs, November 2002, Gig Harbor Basin Plan, Pierce County Water Programs, November 2002, and Muck Creek Basin Plan, Pierce County Water Programs, April 2003.

~~A.~~ B. Clover Creek Basin Drainage Plan, An Engineering Study for Flood Control in Pierce County, Washington, Consoer, Townsend & Associates Consulting Engineers, 1976.

~~B~~C. Hylebos Basin Drainage Plan, Part A, Engineering Study for the Hylebos Flood Control Zone District, Consoer, Townsend & Associates Consulting Engineers, 1974.

D. 144th Street East Drainage Basin Plan, An Engineering Study for Flood Control in Pierce County, Washington, PRC Consoer Townsend, Inc., 1981.

E. Puyallup River Basin Comprehensive Flood Control Management Plan, Pierce County River Improvement, James M. Montgomery Consulting Engineers, Inc., 1991.

~~The following are appendices to the Plan:~~

~~A. North Fork Clover Creek Basin, Preliminary Design Report for Surface Water Control, Project No. D-303 & D-304, David Evans and Associates, Inc., October 1993.~~

~~B. Wollochet Creek Watershed, Hydrologic/Hydraulic and Engineering Analysis, Pierce County CIP Project: 005-D323, Preliminary Engineering Report, Economic and Engineering Services, Inc., March 29, 1995.~~

~~C. Ward's Seeley Drainage System Improvements Predesign, (SWM CIP Project D305-1), CH2M HILL, with Hong West & Associates, Inc., and SvR Design Company, March 1994.~~

~~D. Wards Lake Creek Basin Drainage Basin Improvements, Draft Report, R.W. Beck, August 1994.~~

~~E. Ward's Seeley Drainage System Improvements Predesign, SvR Design Company, February 9, 1995. (Memorandum to John Rogers from Maureen Kwolek.)~~

~~F. Results of Subsurface Site Investigation and Infiltration Analysis, Ward Steilacoom Project Area, Hong West & Associates, March 27, 1995. (Technical Memorandum to John Rogers from Otto Harris and Larry West.)~~

~~G. Pierce County Drainage Study of Clover Creek, Technical Memorandum Project D404, KCM, Inc., December 23, 1994.~~

~~H. Woodland Creek Detention Pond Project No. D-310, Modeling and Assessment Report, Parametrix, Inc., September 1993.~~

~~I. Woodland Creek Bypass Pipeline Project No. D-310-1, Parametrix, Inc., July 1994.~~

~~J. Clear Creek Drainage Basin Feasibility Study, Project Number D-308, Technical Memorandum A, Detention Alternative Documentation, D'Aboy Engineering, Inc., September 1994.~~

~~K. Clear Creek Drainage Basin Feasibility Study, Project Number D-308, Technical Memorandum B, Bypass Pipeline Alternative Evaluations, September 1994.~~

~~L. Chambers-Clover Creek Watershed Action Plan, prepared by Pierce County Public Works and Utilities, June 1997, and recognized by Pierce County Council Resolution R2000-100, October 2000.~~

~~M. Key Peninsula - Gig Harbor - Islands Watershed Characterization & Action Plan, prepared by Key Peninsula/Gig Harbor/Islands Watershed Committee, July 1999, and recognized by Pierce County Council Resolution R2000-101, October 2000.~~

Code Revisor's Note: The Storm Drainage and Surface Water Management Plan was adopted by Ordinance No. 91-113 and codified as Chapter 19D.60 PCC by Ordinance No. 96-111. The Muck Basin Plan was adopted by Ordinance No. 2003-62, and codified as Chapter _____ PCC.

Contents

Part IV SEIS

Tables

Figures

Appendices

Muck Creek Basin Plan
Executive Summary

ES.1 Introduction and Purpose

The 2003 Muck Creek Basin Plan (Basin Plan) is a comprehensive guide to surface water management in the Muck Creek Basin. The Plan focuses on multiple aspects of surface water management, including water quality, flooding, and habitat issues. This Plan was developed as part of Pierce County's Basin Planning Program to create a more focused approach to watershed management in each of the County's major drainage basins. Previously, the Pierce County Storm Drainage and Surface Water Management Plan (1991 Plan) directed surface water management throughout the county for over a decade. As the Plan addressed all basins in the County, only one chapter in the Plan addressed issues in the Muck Creek Basin. The 1991 Plan has been used as a source of information on pertinent studies, plans, and regulatory mechanisms related to water resources in the Muck Creek Basin. Muck Creek Basin is one of 26 basins in Pierce County Figure S-1, "Watersheds of Pierce County."

The purpose of the Muck Creek Basin Plan is to ensure that limited financial and staff resources are applied to the best capital facility projects and programs. To that end, the Basin Plan strategically identifies and evaluates surface water management issues in the Basin and recommends a comprehensive set of projects and programs to reduce flood hazards and drainage problems and improve water quality and habitat throughout the Basin. Actions contained in the Basin Plan are costed-out over a ten-year period and will guide annually updated work plans for capital improvement projects and programmatic measures. ("Programmatic" refers to non-structural actions, such as changes to regulations, policies, programs, or operations.)

The Basin Plan supports (or furthers) Pierce County's:

- Compliance with its federal Clean Water Act National Pollutant Discharge Elimination System (NPDES) municipal stormwater permit;
- Compliance with the Endangered Species Act (ESA) by eliminating or reducing existing potential habitat issues that could cause "jeopardy" for protected species;
- Upgrade to a Class 4 Community Rating under the Federal Emergency Management Agency's (FEMA) Community Rating System (CRS);
- Hazard Mitigation Planning, as required by FEMA (as a result of congressional action) to retain eligibility for federal disaster relief funds; and
- Submittal to the Washington Department of Fish and Wildlife (WDFW) for a programmatic approval agreement under RCW 77.55.100, which allows for programmatic approval in lieu of project-by-project permitting.

ES.2 Goals of the Muck Creek Basin Plan

Specific goals of the Muck Creek Basin Plan are listed below. The full list of goals and objectives can be found in "Appendix O."

Goal 1) Reduce flood hazards
Goal 2) Improve water quality
Goal 3) Improve fish and wildlife habitat
Goal 4) Coordinated and responsible use of public resources
Goal 5) Influence location and methods for new development

ES.3 Description of Basin

Located in southwest Pierce County, the Muck Creek Basin is the largest tributary in size in the Nisqually River Watershed. The Basin includes Muck Creek and three significant tributaries (Figure S-2): Lacamas Creek, the North Fork of Muck Creek and the South Fork of Muck Creek (also known as South Creek). The Muck Creek Basin is approximately 93 square miles in size with elevations ranging from 140 to 960 feet. The topography of the Basin is generally flat to moderately rolling hill terrain. The only substantial relief in the Basin is the hills along the upper portion of the North Fork of Muck Creek and the canyon formed by the lower stretch of the creek as it flows into the Nisqually River. The creek flows across broad natural prairies with native grasses oaks and through local second-growth coniferous and hardwood-forested riparian habitats. The climate of the Muck Creek Basin is mild. It receives around 40 inches of precipitation annually, almost all as rain.

The majority of the Muck Creek Basin is rural in nature. It is characterized by agricultural, forest, pasture and prairie areas with low-density residential development. The largest population center is the unincorporated Graham area in the northeast portion of the Basin. The only incorporated city in the Basin is the City of Roy. Much of the Basin is a patchwork of small (hobby) farms and ranches, interspersed with larger working cattle ranches and timber lots. Fort Lewis occupies a large percentage of the northwestern portion of the basin. Currently, about 24,000 people reside in the Muck Creek Basin. The population is expected to grow, modestly, to 28,000 by 2020.

Much of the stream channel of the South Fork and the main stem of Muck Creek goes dry during the summer and early fall months. This appears to be a natural condition and is primarily due to the highly infiltrative glacial deposits that cover the middle portion of the Basin. The few long-term groundwater records that exist for the Basin show no declining or increasing trend in groundwater levels. Future water use (Year 2030) in the Basin is projected to represent only about 7 percent of the estimated annual groundwater recharge in the Basin. Water use in the Basin is not anticipated to substantially affect either long-term surface flows or groundwater levels.

Muck Creek supports an important chum salmon run, primarily in the lower and middle reaches of the main stem, below State Route 7. Lesser numbers of steelhead and coho have used the stream, although it has been more than a decade since coho have been seen.

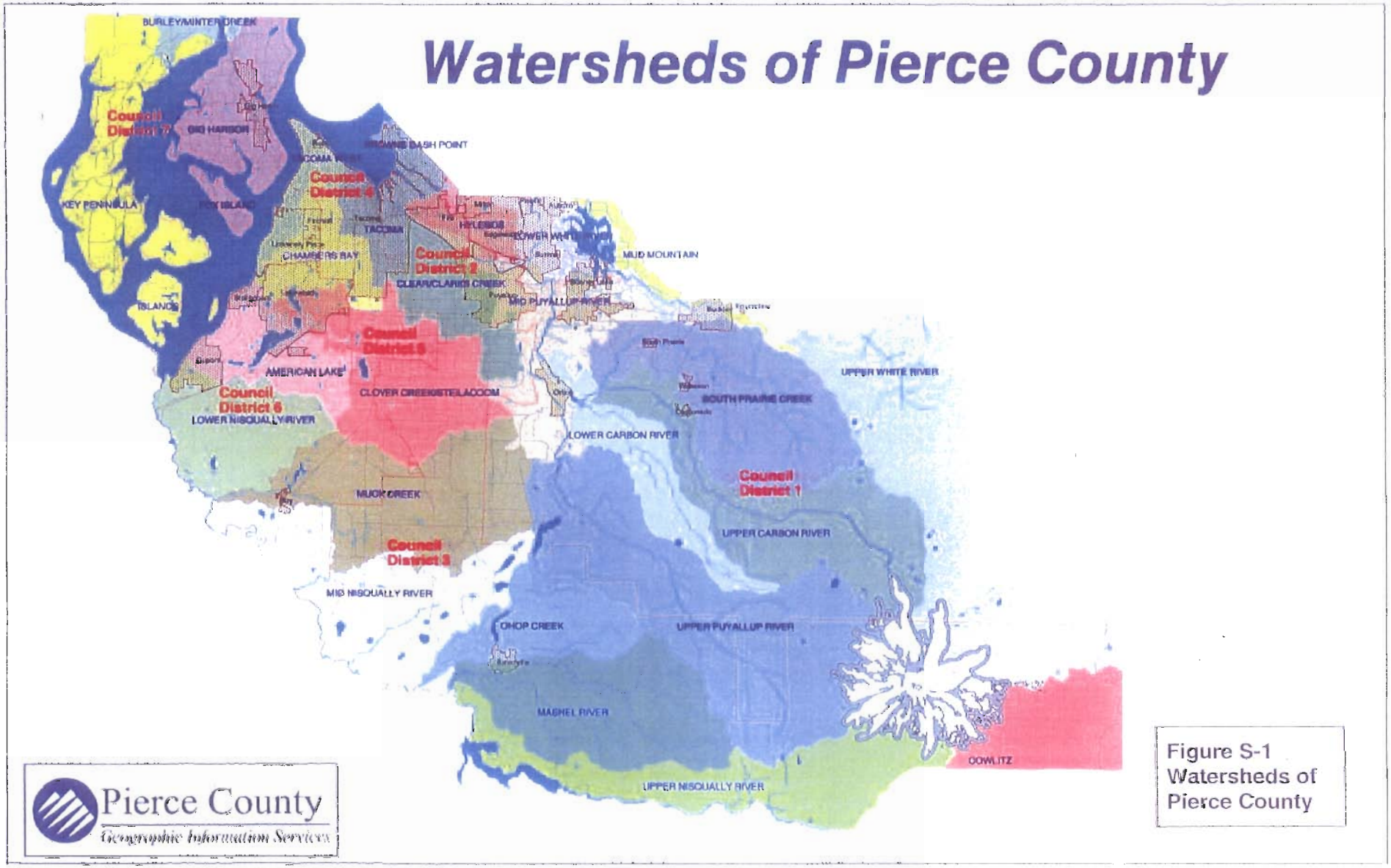
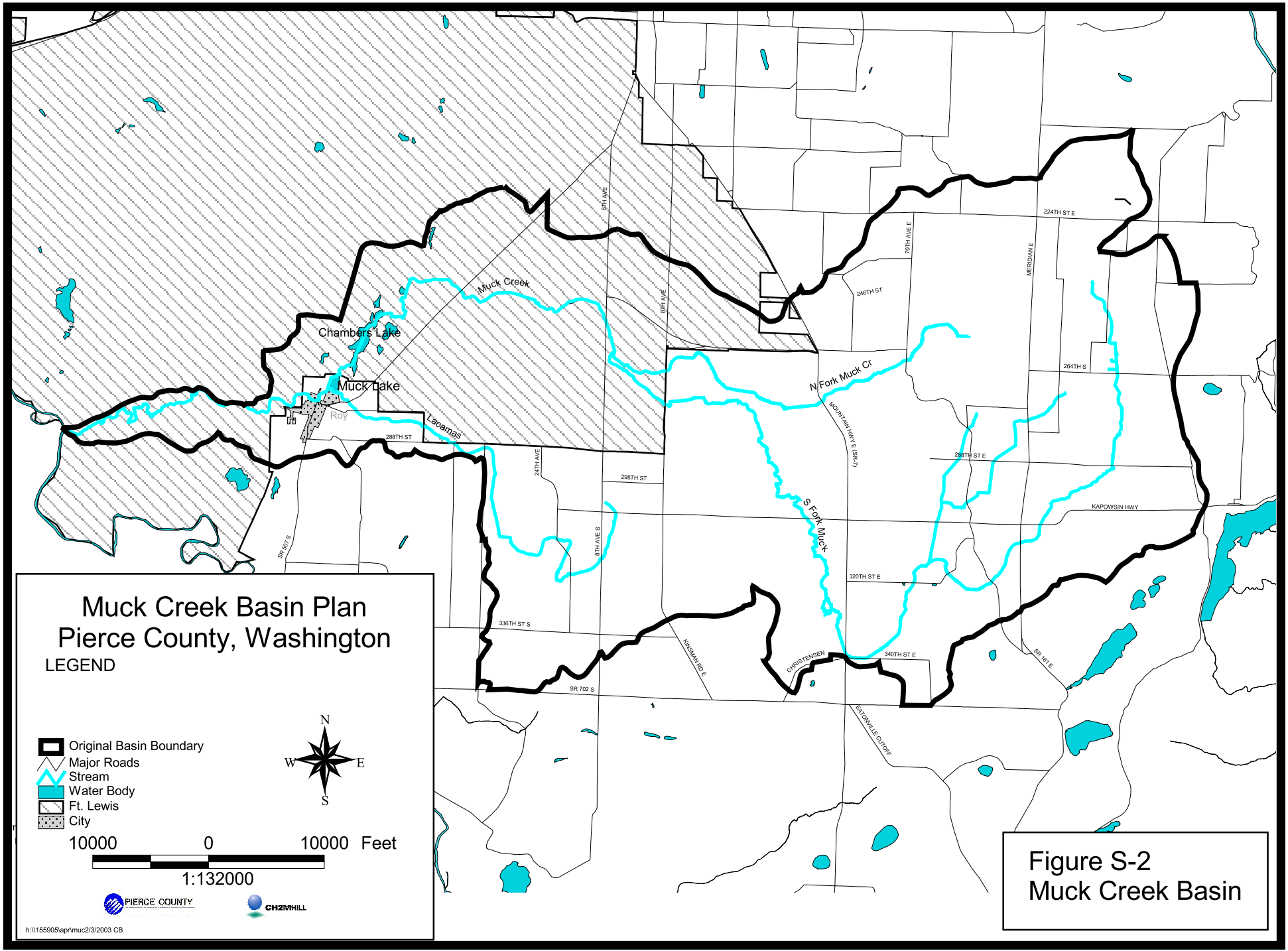


Figure S-1
Watersheds of
Pierce County


Muck Creek Basin Plan
Pierce County, Washington
LEGEND
Original Basin Boundary
Major Roads
Stream
Water Body
Ft. Lewis
City
N
W
E
S
10000 0 10000 Feet
1:132000
PIERCE COUNTY
CH2MHILL
h:\\155905\apr\muc2/3/2003 CB
Figure S-2
Muck Creek Basin
Muck Creek
Chambers Lake
Muck Lake
Roy
Lacamas
N Fork Muck Cr
S Fork Muck
288TH ST
298TH ST
320TH ST E
336TH ST S
340TH ST E
SR 702 S
SR 507 S
224TH ST E
246TH ST
264TH S
288TH ST E
KAPOWSIN HWY
MOUNTAIN HWY E (SR-7)
MERIDIAN E
70TH AVE E
8TH AVE
24TH AVE
8TH AVE S
KINSMAN RD E
CHRISTENSEN
SR 161 E
EATONVILLE CUTOFF

ES.4 Stakeholder and Public Involvement

Two public meetings were held in February 2000, early in the study, to describe the basin planning process and to solicit information at the beginning of Phase 1. Two additional public meetings were held near the end of Phase 1, in August 2000, to describe the findings and discuss activities for developing the Basin Plan in Phase 2. In addition, presentations were made at several meetings of the Muck Creek Council and the Nisqually River Council and with the Nisqually Indian Tribe. A more detailed description of stakeholder involvement efforts may be found in Chapter 3.

The Draft Basin Plan and the accompanying Draft Supplemental Environmental Impact Statement were made available to the Pierce Conservation District, Muck Creek Council, Nisqually River Council, Nisqually Tribe, Fort Lewis, City of Roy, and other interested or affected parties as determined by Pierce County Water Programs staff for public comment. The Draft Supplemental Environmental Impact Statement was issued on February 12, 2003 and the comment period ended March 14, 2003. A notice announcing the availability of the Draft Basin Plan/DSEIS was distributed to attendees of previous meetings and other interested residents. Two public meetings were held during the DSEIS review period. One public meeting was held in Roy, Monday, March 3, 2003 at the Roy Library. A second public meeting was held at the Graham Library on March 5, 2003. The draft and final plans were also posted on the Pierce County Water Programs website.

Additional public involvement opportunities will occur annually through the Pierce County Planning Commission and County Council actions on the capital facilities plan.

ES.5 Problems, Proposed Solutions and Prioritization Process

The results from this study indicate that there are no major flood problems in the Basin. However, road flooding does occur and is attributable to undersized culverts and to ponded runoff which collects in local depressions. Some residences are also impacted by ponded runoff which collects in local depressions after heavy rain events. Compared to many other basins in the Puget Sound area, the water quality of the streams in the Muck Creek Basin is relatively good. However, water temperature and bacteria (i.e., coliforms) levels commonly exceed state water quality standards. Past agricultural development in the Basin has channelized many of the stream reaches and removed riparian vegetation. Direct livestock access to streams has severely eroded the stream channels at a number of locations. As a result, less than 15 percent of the stream reaches in the Basin provide good fish habitat for anadromous fish.

Each of the Basin Plan's capital improvement projects and programmatic recommendations were evaluated using a spreadsheet that assigned points for the project/program's potential for various aspects of flood reduction (approximately 35% of total score), water quality protection or improvement (30%), natural resource improvement (30%), and other factors such as multiple

use, education, and recreation (5%). Each project and program was reviewed and scored using approximately 40 specific criteria.[1]

A scoring summary was prepared for each proposed project and a scoring worksheet for each proposed programmatic measure. These can be found in "Appendix M" of the Basin Plan. Recommended projects and programs were then put in rank order, based on their numeric benefit score, and grouped in descending order. Then, high, medium, or low status was assigned as follows:

- High Priority: 25% of total number of recommendations
- Medium Priority: 50% of total number of recommendations
- Low Priority[2]: 25% of total number of recommendations

After this order was established, projects and programs were ranked within their priority category from lowest cost to highest cost. This was done to direct County financial resources to where they do the most good for the financial resources invested.

ES.6 Recommended Actions

Twenty-one capital improvement projects are recommended in the Basin Plan. These include two regional infiltration basins, a number of culvert upgrades and improvements to several local drainage systems are proposed. In addition potential areas for stream and riparian restoration projects are identified. In addition to improving potential fish habitat, the riparian restoration projects will help to address the water temperature and bacteria water quality problems. It should be noted that maintenance costs were not included in the cost estimates for the capital improvement projects. Pierce County has an existing maintenance program, but may need to evaluate the ongoing cost of supporting that program as projects are completed.

Programmatic recommendations in the Muck Creek Basin Plan are:

- Conduct a Low Impact Development Pilot
- Adopt updated stormwater management standards
- Increase compliance inspections
- Develop and implement a land acquisition program for riparian and wetland habitat protection and flood hazard reduction
- Develop and implement a program to enhance degraded riparian habitat and water quality

1 Programmatic measures were eligible for additional points in the rating system to implement Pierce County's policy preference for favoring "non-structural measures" over "structural measures." This policy preference was stated and adopted in the 1991 Plan and again in the County's Comprehensive Plan.

2 Note: "low priority" does not mean "no benefit" for flood control, water quality protection, or natural resource protection. All of the recommendations in the Basin Plan provide a net benefit to these objectives. "No benefit" proposals were screened out prior to preparation of the Plan. "Low Priority" means that the proposed project or program scored lower that other projects and programs, based on the net environmental benefits that would occur from the project or program as determined by the score sheet criteria. Some projects that are ranked "medium priority" or "low priority" will be considered for implementation prior to other projects to ensure the full benefits of other projects, such as upstream fish habitat improvements are synchronized with downstream barrier removal.

- Develop and implement an education, outreach, and technical assistance program
- Develop and implement a surface water management monitoring program
- Develop and implement a BMP manual for Pierce County Surface Water Utility maintenance activities
- Develop and implement an invasive species management program

Prioritized measures recommended in the Plan over a ten-year period total $10.5 million. This includes $9.9 million for capital improvement projects and $0.63 million for programmatic recommendations (*Table ES-1*). Of the total amount:

- $3.5 million is for actions identified as “High Priority”;
- $6.5 million is for actions identified as “Medium Priority”;
- $0.54 million is for actions identified as “Low Priority”;

Four studies are also recommended in this Plan. Their combined cost is an additional $0.43 million.

- Evaluate groundwater migration near the Northeast Muck Creek/Clover Creek Basin boundary
- Identification of flooded depression areas
- Detailed flood study along the South Fork upstream of Mountain Highway
- Identification of significant wetland sites

Once this Basin Plan is adopted, these measures will be added to the County-wide surface and stormwater CIP List, joining the CIP requirements of other basins within Pierce County. The common ranking and cost system used to develop these basin-level CIP lists will aid in the overall ranking of each CIP at the County level.

ES.7 Implementation Strategy

Implementation of the recommended actions will generally follow the prioritization groupings of high, medium, and low and a logical order of sequencing.

To ensure that the full benefits of all projects are realized, implementation will not follow the exact sequence of the first project to the last project in the “High” category, followed by the first action in the “Medium” category, and so forth.

Several factors exist that will result in implementation of actions that are not in the exact sequence as depicted in the projects and programs prioritized by the benefit and ranked by cost table.

These factors include the following:

- Available funds;
- Contingent projects[3];
- Available staff and professional service needs;
- Cooperation from private landowners;
- The best implementer may be an agency other than Pierce County Public Works and Utilities; and
- New information, regulations or emerging issues.

Economic Development Criteria

Implementing projects and programs recommended in the Basin Plan is expected to reduce flood hazards, and preserve or protect water quality and floodplain habitat. Collectively and individually, these projects are aimed at protecting Pierce County's quality of life. Projects and programs in the Plan will afford resource protection as the community develops; preserve, enhance or protect natural floodplain functions; balance structural and nonstructural approaches; reduce potential County environmental liabilities; and help achieve environmental compliance and long term sustainability. Collectively, these attributes help make Pierce County a livable community where quality of life issues will provide indirect, passive economic development benefits to businesses and individuals looking to locate or stay in Pierce County.

In addition to the above, Water Programs will consider the following criteria in developing its annual proposed capital facilities plan updates:

- Is the project located in an employment center zone (or handle flow from those zones)?
- Is the project located in another type of commercial zone (or handle flow from those zones)?
- Will the project reduce permitting timelines for industrial/commercial projects?
- Will the project assure access to an employment center via road and /or rail?
- Will the project increase the supply of developable property?
- Will the project reduce overall development costs?
- Are there partners willing to contribute to the development costs of the project?
- Does the project allow / provide for land development?

In light of these and other factors, following action on the Basin Plan, Pierce County will develop an implementation strategy designed to sequence, schedule and assign resources for the various recommended actions. This implementation strategy will be developed in collaboration and coordination with other potential implementers and in consideration with available financial and staff resources. The implementation strategy will include performance measurements and provide for periodic evaluation of progress.

[3] Contingent projects include projects such as stream restoration projects intended to reduce flood hazards and improve aquatic habitat, and culvert replacement projects intended to improve fish passage. These projects will provide their full benefit after all downstream fish passage barriers are removed, and should be sequenced accordingly.

Principle Implementer, Financing Strategy and Timing

Generally, the implementer responsible for the recommendations contained in this report is Pierce County, principally, Pierce County Water Programs either individually or in partnership with other entities. Funding of these recommendations is mainly through Pierce County's surface water management fees collected within the Basin, but may also include general fund, state and federal grants, and other local funds. Currently, this Plan projects full implementation out over a ten year period beginning in 2003. The actual duration of full implementation and the timing of specific projects and programs are determined through annual budget decisions of the County Council concerning the Capital Facilities Plan and operating budget.

TABLE ES-1
Prioritized List of Proposed Projects – Muck Creek Basin 2003

Priority	Project Name	CIP Number	Score	Est. Cost	Priority Ranking	Total Costs
1	Adopt updated stormwater mgt. standards	PG00-02	380	$ 1,000	High	
2	Maintenance BMP Manual	PG00-08	427	$ 7,000	High	
3	Invasive Species Management	PG00-09	420	$ 7,000	High	
4	Implement riparian land acquisition pgm.	PG00-04	389	$ 9,000	High	
5	Implement education/tech. assistance pgm.	PG00-06	397	$ 111,000	High	
6	Increased inspections	PG00-03	398	$ 204,000	High	
7	Lacamas Creek Habitat Restoration	CIP12LC-STR01	375	$ 1,444,000	High	
8	North Fork Habitat Restoration	CIP12NF-STR01	380	$ 1,748,000	High	
	Subtotal					$3,531,000
9	Implement riparian & WQ enhancement pgm.	PG00-05	325	$ 34,000	Medium	
10	288th St E Culvert Replacement II	CIP12SF-CUL03	165	$ 41,000	Medium	
11	Meridian E Culvert Replacement	CIP12SF-CUL05	195	$ 46,000	Medium	
12	Conduct a low impact development pilot	PG12-01	346	$ 100,000	Medium	
13	Schudy Rd S Culvert Replacement	CIP12LC-CUL01	175	$ 100,000	Medium	
14	288th St E Culvert Replacement I	CIP12SF-CUL01	180	$ 128,000	Medium	
15	288th St E Culvert Replacement III	CIP12SF-CUL04	170	$ 133,000	Medium	
16	Implement surface water monitoring pgm.	PG00-07	244	$ 158,000	Medium	
17	252nd St E Conveyance Improvements	CIP12NF-CUL03	155	$ 179,000	Medium	
18	288th St S Infiltration Pond	CIP12MS-INF01	115	$ 297,000	Medium	
19	336th St S Grade Change	CIP12LC-RD01	150	$ 303,000	Medium	
20	Highway 507 Culvert Replacement	CIPLC-CUL02	215	$ 345,000	Medium	
21	South Fork Habitat Restoration	CIP12SF-STR01	365	$ 608,000	Medium	
22	Patterson Springs Acquisitions	CIP12NF-ACQ01	265	$ 1,500,000	Medium	
23	Graham Regional Stormwater Facility	CIP12NF-XXX	200	$ 2,500,000	Medium	
	Subtotal					$6,472,000
24	238th St E Conveyance Improvements	CIP12NF-RD01	45	$ 2,000	Low	
25	216th St Conveyance Improvements	CIP12NF-CUL01	45	$ 4,000	Low	
26	Kapowsin Highway Conveyance Improvements	CIP12SF-CUL02	85	$ 10,000	Low	
27	47th Ave E Conveyance Improvements	CIP12SF-PIP01	60	$ 34,000	Low	
28	70th Ave E Culvert Improvements	CIP12NF-CUL02	100	$ 39,000	Low	
29	242nd St E Infiltration Pond	CIP12NF-INF01	85	$ 136,000	Low	
30	Mountain Highway Conveyance Improvements	CIP12SF-DIV01	95	$ 319,000	Low	
	Subtotal					$544,000
31	Graham Groundwater Flow	ST12-01		$ 205,000	Not Prioritized	
32	Identification of Potholes	ST12-02		$ 90,000	Not Prioritized	
33	South Fork Flood Study	ST12-03		$ 60,000	Not Prioritized	
34	Wetland Site Identification	ST12-04		$ 70,000	Not Prioritized	
	Subtotal					$425,000

Total Estimated Cost of Plan Implementation (Cost changes reflect rounding) **$10,972,000**

CHAPTER ONE

Introduction

The Pierce County Water Programs Division within the Public Works and Utilities Department (Water Programs) is preparing a series of basin plans to address flooding, water quality and habitat problems in the major stream systems of the non-federal lands in the county. These plans update the county-wide *Storm Drainage and Surface Water Management Plan* developed in 1991 (Montgomery Engineers Inc., 1991). Each plan addresses in more detail the flooding, water quality and stream habitat problems in a particular basin. These plans incorporate the requirements of major regulations that have been enacted since the previous, county-wide 1991 plan, including the State Growth Management Act, NPDES requirements of the Clean Water Act, and the fish listings under the Federal Endangered Species Act. The basin plans will be implemented through Water Programs activities.

Water Programs is responsible for surface water management in unincorporated areas of the county. The Division plans, designs, permits, builds and maintains surface water management facilities. Property owners are charged a fee for surface water management services. Water Programs is also responsible for compliance with the stormwater quality management requirements of the federal Clean Water Act. Other related Water Programs responsibilities include river and levee maintenance, stream gauging and water quality monitoring, gathering of rainfall data, emergency response during floods, water supply planning and public education regarding stormwater quality and quantity.

This Basin Plan addresses the Muck Creek Basin. Muck Creek is located in the southwestern portion of the county and is the largest tributary to the lower Nisqually River. A vicinity map showing the Muck Creek Basin is found in Figure 1-1. This Plan consists of three major parts, as outlined below.

1.1 Basin Plan Organization

Part I is the Basin Characterization Report, which is covered in Chapters 1 through 5. The Basin Characterization Report describes environmental attributes throughout the Watershed including high quality stream reaches, associated wetlands, sensitive areas, and the Basin's abilities to support various fish species, especially those species listed or potentially subject to future listing under the Endangered Species Act. The Characterization identifies stream reaches and associated subbasins that do not meet State water quality standards, areas of localized flooding, and aquatic habitat segments that have been impacted or are threatened. The potential for environmental degradation throughout the Basin due to future land use changes is described qualitatively.

Part II is the Basin Plan Analysis (Chapters 6 through 8). Problems and potential solutions are reviewed for drainage/flooding, water quality and stream habitat. Part III covers the Basin Plan, itself, in Chapter 9. Finally, Part IV consists of a supplemental Environmental Impact Statement (EIS) of the Plan in Chapter 10. The EIS supplements information from the EIS on the original 1991 plan.

The Basin Plan outlines a set of goals for preservation and restoration of the Basin's environmental water resources. These goals will be translated into a comprehensive list of Basin needs and action recommendations, including projects, programs, and policies to address the water quality, flooding, and habitat problems identified in the Plan.

These action recommendations direct Pierce County's future surface water management capital improvement projects, water resource protection programs, and public education programs in the Muck Creek Basin.

The Basin Characterization and Basin Plan are the first two phases of the planning process. Following adoption of the Basin Plan, a third implementation phase will occur. This implementation phase will include a long-term monitoring process. The monitoring will analyze the progress of the capital improvement plan implementation and the effectiveness of capital improvement projects. It will also look at stream and Basin characteristics, and serve to identify potential modifications to the plan that might better serve to meet plan objectives.

1.2 Statement of Purpose

The stated purpose of the Muck Creek Basin Plan is to create a comprehensive approach to reducing flood hazards, improving fish and wildlife habitat, and improving water quality throughout the Basin by updating the Pierce County Storm Drainage and Surface Water Management Plan.

Much has happened since the development of the County's Storm Drainage and Surface Water Management Master Plan (refer to Section 2.1) more than 10 years ago. There has been a growing emphasis on the protection of streams, wetlands and other environmentally sensitive areas. In the early 1990s the State Growth Management Act led to the protection of environmentally sensitive areas, such as wetlands and streams, and a requirement for protection of adjacent buffer areas. In 1995, the Washington State Department of Ecology issued an NPDES municipal stormwater permit to Pierce County requiring water quality protection under the federal Clean Water Act. In the late 1990s the federal government listed Chinook salmon, bull trout and other fish species under the Endangered Species Act. This has resulted in further scrutiny of development regulations and increased stormwater control measures. Emerging trends, such as low-impact development, show promise in limiting the impacts of growth and development.

Muck Creek supports an important run of chum salmon in its lower reaches. It is a primarily rural Basin, but the stream has been impacted by widespread grazing and agricultural activities. The northeastern portion of the Basin lies on the southern fringe of a rapidly growing area of Pierce County. The widely scattered drainage and flooding problems typical of a rural Basin could intensify with increased development. Many of the stream reaches and much of the main stem of Muck Creek flow intermittently, drying out during the late summer and early fall. There is concern that additional development in the Basin may further aggravate this situation. This basin planning process reviews and addresses Basin problems and recommends development strategies that facilitate growth in a manner compatible with preservation and enhancement of the water resources and aquatic habitat of the Muck Creek stream system and to ensure that flood control and water quality issues within the Basin are addressed.

1.3 Goals and Objectives

When Pierce County's planning process for Basin Plans was developed, a purpose statement along with goals and objectives for the Plans were established. Those goals and objectives are included as "Appendix O" of this document. In summary, the goals are intended to achieve the Plan purpose. Simply restated, they are to reduce flooding, improve habitat, improve water quality, ensure responsible use of public resources, and to provide guidance for new development.

CHAPTER TWO

Existing Programs and Information

2.1 Pierce County Programs

2.1.1 1991 Storm Drainage & Surface Water Management Plan

Over a decade ago, the Pierce County Storm Drainage and Surface Water Management Plan (1991 Plan) was completed (Montgomery Engineers, 1991). This Plan contained structural and nonstructural measures to address flooding and water quality problems areas in the County. Muck Creek was one of the basins. Many of the stormwater projects carried out by the Water Programs Division were identified by the 1991 Plan.

The 1991 Plan recommended upgrades to a number of culverts that were determined to be undersized. Five of these culverts were categorized as high-priority projects due to their risk of over-topping and impacting traffic. These culverts are further analyzed in Chapter 6. The 1991 Plan also recommended increasing the channel capacity of a portion of Lacamas Creek, removing reed canary grass and sediment to reduce flooding. This measure is one of the fish habitat improvement projects proposed in this current Basin Plan.

In 1988 the Pierce County Storm Drainage and Surface Water Management Advisory Board (SWMAB), a County-wide group of individuals representing each major watershed of the County was established to assist in the development of the Pierce County surface water utility plan and to assist in guiding the program. After the 1991 Plan was adopted, the Board dissolved. The County Council reestablished the SWMAB in 2004. There are nine board members, representing the major watershed basins within the County, who review the surface water utility program. SWMAB meetings are open to the public.

2.1.2 Pierce County Comprehensive Plan

In 1994 Pierce County adopted its Comprehensive Plan, Title 19A, Pierce County Code, pursuant to the requirements of the Washington Growth Management Act. The Comprehensive Plan contains policies that are intended to facilitate land development and balance that development with protection and preservation of natural resources. Policies addressing surface water management can be found in the Land Use, Environment and Critical Areas and Utilities and Capital Facilities Elements of that Plan. Regulations that implement the Comprehensive Plan, especially the Critical Areas Regulations, influence the design and location of surface water management facilities. The 1991 Plan is considered to be part of the Comprehensive Plan.

2.1.3 Pierce County's NPDES Municipal Stormwater Permit

In 1995, the Washington State Department of Ecology issued an NPDES permit to Pierce County under the federal Clean Water Act. The permit requires the County to implement a

program of controls, inspections, standards, and outreach for water quality protection. This Basin Plan furthers the County's compliance with that permit.

2.1.4 Graham Community Plan

A land use plan has been initiated in the Graham community (See Figure 2-1, Graham Community Plan Area). A large portion of the community plan area is within the Muck Creek Basin. Information developed during preparation of the Basin Plan will be provided to the Graham Community Planning Board for support in developing the community plan.

2.1.5 Stormwater Facility Mapping

In 1999, Pierce County initiated a 3-year program to survey every county-maintained drainage facility. The survey is a cooperative effort between County agencies. Global positioning equipment is being used to accurately tie in the drainage structures to the county geographic information system (GIS) database. The drainage inventory for the Muck Creek Basin was completed in 2001 and has been incorporated into this Plan.

2.2 Other Programs, Policies and Regulations

There are a number of federal and state programs contain standards and provisions that influence development of the basin plans. Some of the more significant ones are summarized in *Table 2-1*. The programs are explained in more detail within Pierce County Water Programs *Guidance for Basin Planning* (2000).

Table 2-1 Summary of Regulations Relevant to Basin Planning

Law or Regulation	Implications for Basin Planning
Clean Water Act	• Coordinate basin planning with stormwater management planning pursuant to County's NPDES stormwater permit. • Check status of waterways with respect to 303(d) list and calculation of TMDLs. • Avoid recommending projects that involve filling wetland to the extent possible. • Address activities which have adverse impacts to water of the United States.
Endangered Species Act	• Basin plans should include projects that protect and enhance listed species, particularly salmonids and to reduce potential jeopardy tothese species from Pierce County actions.
National Flood Insurance Program	• Recommended projects should comply with flood plain regulations. • Basin plans should be designed to serve as flood mitigation plans for community rating purposes.
Safe Drinking Water Act	• Recommended projects should have no adverse effect on groundwater quality.

Law or Regulation	Implications for Basin Planning
State Water Quality Standards	• Recommended projects must not cause violations of state standards for ground and surface waters.
Growth Management Act	• Plans should provide science for community plan policy recommendations • Coordinate basin planning with community planning. Projects comply with critical area regulations (avoidance, adequate buffer offsets, etc.)
State Environmental Policy Act	• Basin plans must be accompanied by a SEPA compliance document which includes an impact analysis and appropriate mitigation.
Shoreline Management Act	• Recommended projects must comply with SMA requirements, if applicable.
State Hydraulic Code	• Recommended projects must comply with State Hydraulic Code, if applicable.
Watershed Management Act	• Coordinate basin planning with larger-scale watershed planning.
State Shellfish Management Regulations	• Presence of shellfish downstream of a basin should be a factor in prioritizing recommended projects.

Source: URS (2000)

2.3 Other Programs, Studies and Reports Relevant to the Basin Plan

2.3.1 Nisqually River Management Plan

In 1987, the Nisqually River Management Plan (NRMP) presented a comprehensive plan for managing the river and its watershed. The Plan was prepared by the Nisqually River Task Force, a group of stakeholders convened by the Department of Ecology in response to SHB 323, in which the State Legislature directed Ecology to prepare an overall plan for management of the Nisqually River and to provide guidance for stewardship of the economic, cultural and natural resources of the river Basin. The NRMP is implemented by the Nisqually River Council, a group of stakeholders which includes government, citizens, other interest groups and the Nisqually Tribe. Muck Creek is identified within the NRMP as a "Stewardship Management Zone".

2.3.2 Muck Creek Stream-Groundwater Interaction Study

In the summer of 1999, the Washington State Department of Ecology (Ecology) initiated an investigation of the ground and surface water interactions along Muck Creek. This study was designed to shed light on the locations and seasonality of water losses from Muck Creek. A series of piezometers were placed in the stream channels. The local water table level was measured at monthly intervals to determine how the ground and surface waters interact along the stream. Flow measurements were also taken at multiple points along the stream system to

determine sections that are gaining and losing streamflow. During the development of this study, a cooperative effort occurred between Ecology and the Pierce County team to gather flow data. A report presenting the results of this study was issued at the end of 2001 (Sinclair, 2001). The results are discussed in Section 4.4.

2.3.3 Fort Lewis Stream Studies

Fort Lewis commissioned two studies of the streams within its boundaries, including Muck Creek. One of the studies, which began in May 2000, is to document stream resources and the impacts that Fort operations have on the streams. The study included the installation of additional piezometers to compliment the Ecology study discussed above, stream surveys, and collection of stream biological and water quality data. A major objective of this study is to develop recommendations to preserve or upgrade the aquatic habitat of Muck Creek (Clouse 2000, personal communication). Due to unusually dry conditions during 2000-2001, the stream flow and piezometer portion of this study was delayed for a year; thus, the final report was not available at the time of this Basin Plan.

A second study conducted by the Department of Defense to gather information about the impacts of military and non-military operations upon salmonid habitat within military bases was completed in July, 2002 (Christopher May, 2002). Stream and riparian conditions were documented along the main stem of Muck Creek and along the lower portions of the North Fork and Lacamas Creek. The study concluded that the salmonid habitat quality along the creek in the middle and lower ravine (downstream of Roy) was fair to good. The habitat quality in the remaining, on base portion of the creek, up and downstream of Roy, and upstream of Highway 507, was determined to be poor. The on-base portion of Lacamas Creek was rated as poor habitat. The study also found that stream bank stability within the Fort was generally good and concluded that excessive storm flows are not a major problem in the Basin.[1]

2.3.4 Nisqually Watershed Assessment

Supported by funding under the State Watershed Management Act (RCW 90.82 or ESHB 2514), a water resource management plan was initiated in 2000 for the Nisqually River Water Resource Inventory Area (known as WRIA 11). A primary purpose of this study is to evaluate water use and supply within the WRIA. The Nisqually Tribe is leading this effort. The agencies participating in this effort include the Department of Ecology, Pierce and Thurston counties, the cities of Yelm, Lacey, Olympia and Eatonville, the Elbe Water District and Graham Hill Mutual Water Company, the Nisqually River Council and the Nisqually Tribe. A “Level 1 Assessment” has been produced. It includes chapters on the hydrologic framework, fish habitat quality, water quality, stream flow, groundwater, water rights and water use. The lower portion of the river Basin is split into six subbasins for purposes of data presentation. The Muck Creek area is combined with areas which lie north and south of the Muck Creek Basin. This is labeled as the Muck/Murray Subbasin and has a combined area of 181.5 square miles, about twice that of the Muck Creek drainage. Data in the Level 1 Assessment have been incorporated into this document.

[1] The May Study used a stream assessment protocol that was different from the Urban Stream Baseline Evaluation Method used in this Basin Study and the results are therefore not directly comparable.

2.3.5 Water Quality Monitoring

Throughout most of the 1990s Fort Lewis and the Nisqually Tribe collected monthly water quality data along Muck Creek and its major tributaries. This data collection continued until 1999. In the late 1990's Land Recovery Inc. began to collect surface and groundwater data at a large new landfill located near the intersection of Meridian and Kapowsin Highway. The monitoring is continuing. The data from these three efforts are discussed in Section 4-4.

2.3.6 Salmon and Steelhead Habitat Limiting Factors Report

This report, prepared by the Washington State Conservation Commission, reviews the factors which may be limiting fish production within the Nisqually Watershed (Kerwin, 2000). Much of the report concentrates upon the river, itself. Short reviews are presented for the major tributaries, including Muck Creek. The report identifies intermittent streamflow as the major factor limiting fish utilization, particularly pink, coho and chinook salmon. Channel blockage by reed canary grass is another identified factor. Water quality is not identified as a major limiting factor.

2.3.7 Pierce Conservation District

The Pierce Conservation District has surveyed culverts in the Nisqually Basin, including the Muck Creek Basin, to determine likely fish blockages. An inventory of stream crossings has been completed, with an analysis of fish passage issues.

The Conservation District offers several public assistance and education programs. Among them, staff provides rural landowners with technical advice and helps develop farm plans that minimize the adverse effects of agricultural activities on the environment. Implementation of farm plans is voluntary. The Conservation District also carries out riparian and stream habitat improvement projects.

2.3.8 Federal Emergency Management Agency Community Rating System (CRS)

The objective of the (Community Rating System) CRS is to reward communities that are doing more than meeting the minimum requirements of the National Flood Insurance Program. The incentives for communities to go beyond minimum requirements include reductions of flood insurance rates, enhanced responsiveness and a preventive approach to future losses.

In order to realize these benefits, communities must be evaluated and assigned a class status rating of the CRS. The CRS has 10 classes: Class 1 gives the greatest premium reduction; a Class 10 receives no premium reduction. For the year 2003, Pierce County has a Class 5 rating.

The Basin Plan has been prepared using CRS Class 4 or better prerequisites and will be part of Pierce County's overall evaluation.

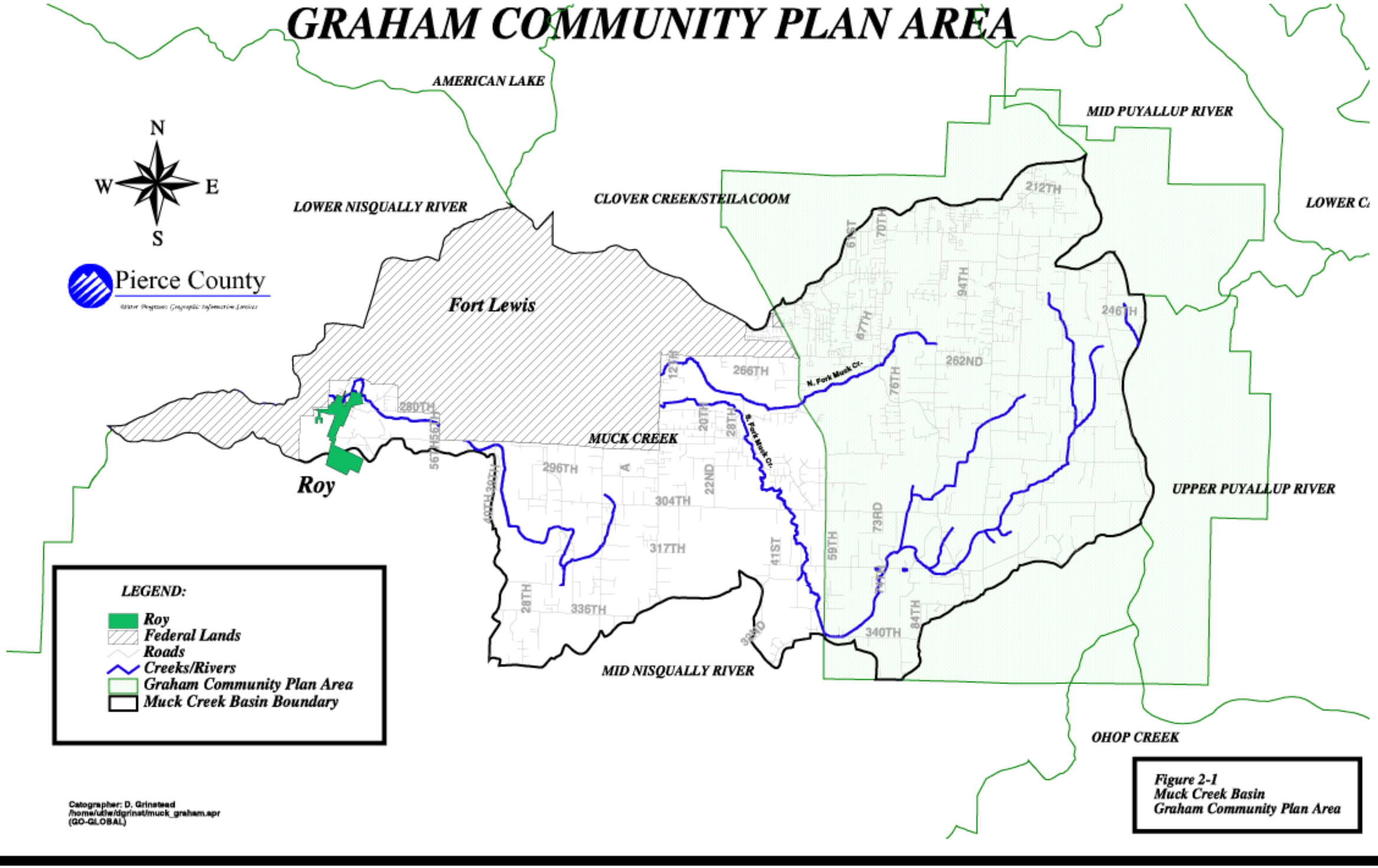
Specifically, the Basin Plan has been prepared to meet or exceed the following:

Floodplain Management Planning Elements
CRS Planning Steps:

1) **Organize**
2) **Involve the public**
3) **Coordinate**
4) **Assess the hazard**
5) **Assess the problem**
6) **Set goals**
7) **Review possible activities**
8) **Draft an action plan**
9) **Adopt the plan**
10) **Implement, evaluate, revise**

This plan incorporates steps 1-8. Pierce County Council Action will be sought to implement steps 9 and 10.

GRAHAM COMMUNITY PLAN AREA



Catographer: D. Grinstead
/home/uthr/dgrinst/muck_graham.apr
(GO-GLOBAL)

Figure 2-1
Muck Creek Basin
Graham Community Plan Area

CHAPTER THREE

Stakeholder Involvement

The development of the Muck Creek Basin Plan has involved participation by stakeholders in the Plan. "Stakeholders" are parties with an interest in the outcome of the Plan.

3.1 Stakeholders

The full range of stakeholders potentially involved in development of the Basin Plan includes federal, state, and local governments; tribes; the U.S. Army; local businesses; farmers; conservation districts; environmental interest groups; other citizen groups; and the general public. Some of the stakeholders are listed below.

3.1.1 Nisqually Tribe

Muck Creek supports a major run of chum salmon within the Nisqually River watershed. This is an important component of the fishery resources utilized by the Nisqually Tribe. The tribe has taken a leading role in planning within the larger Nisqually Basin. The Tribe's long-term data collection program for water quality and fisheries has provided valuable information for this study. The Tribe is currently leading a river basin assessment for the Nisqually River Watershed (refer to Section 2.3). Information on Muck Creek has been compiled under the "Level 1 Assessment" which was recently completed for the Nisqually Watershed (Watershed Professionals Network 2002).

3.1.2 Muck Creek Council

Another stakeholder is the Muck Creek Council, which consists of a group of citizens dedicated to preserving and restoring Muck Creek as a quality aquatic habitat. Established in 1996, the Council meets monthly to discuss issues affecting the creek. The Council promotes stream and riparian restoration projects in the Basin. The Council has provided good information and valuable insight to this study.

3.1.3 Pierce Conservation District

The Pierce Conservation District plays a major role in the dissemination of information on Best Management Practices for water quality improvement. The District works with farmers on farm management measures to improve water quality. In conjunction with the Muck Creek Council, they have been involved with numerous efforts working with volunteer groups to improve the aquatic habitat of the creek. The projects include riparian planting and fencing, removal of reed canary grass, and reconfiguration of channels to improve spawning habitat for salmon.

3.1.4 Fort Lewis

Approximately one-quarter of the Muck Creek Basin lies within the boundaries of Fort Lewis. Nearly all of the active fish spawning and most of the best remaining fish habitat are found within the Fort. The U.S. Army's operations at Fort Lewis can impact the creek, as can activities on private lands upstream of the Fort. Army personnel and contractors have collected water

quality data and conducted stream surveys along sections of Muck Creek that pass through Fort Lewis (Refer to Section 2.3). These efforts continue to provide valuable data for the creek. In addition, Fort Lewis has made improvements to stream habitat in Muck Creek through a number of projects that include reed canary grass control, riparian tree planting, and channel enhancements. Fort Lewis will play a key role in overall restoration and maintenance of stream habitat in the Main Stem of Muck Creek.

3.1.5 City of Roy

This small city is the only incorporated entity within the Basin. The City addresses drainage problems within its jurisdiction.

3.1.6 Nisqually River Council

The Nisqually River Council was formed in 1987 to coordinate the interests of multiple jurisdictions, the Nisqually Tribe, organizations and citizens in implementing the Nisqually River Management Plan and enhancing the resources of the River Basin. The Council has undertaken public education initiatives and the Nisqually River Land Trust arm of the Council has been instrumental in the acquisition and preservation of sensitive areas within the River Basin.

3.1.7 Washington State Department of Ecology

The Washington State Department of Ecology has regulatory authority for water rights to both ground and surface waters in the Basin. The Basin has been closed to any new surface water rights for many years. Ecology also has the responsibility for assuring that water quality standards are met. In this regard the Department may issue permits to regulate discharges to stream or groundwater. Ecology also oversees Pierce County's NPDES municipal stormwater permit. It also administers the State Water Pollution Control Act (RCW 90.48) and is the State's delegated agency for oversight of the federal Clean Water Act. Both of these laws authorize Ecology to bring enforcement actions against entities or individuals for purposes of pollution abatement.

3.1.8 Graham Land Use Advisory Commission (GLUAC)

The GLUAC is a group of citizens appointed by the County Executive and confirmed by the County Council. The group reviews land use application proposals within the Graham Community and participates in the development of the Graham Community Plan. Information gathered in utilizing the development of the Basin Plan has been shared with the GLUAC.

3.1.9 Graham Community Planning Board

The Community Planning Board is a group of citizens appointed by the County Executive and confirmed by the County Council to develop the Graham Community Plan. The group has expressed interest in some of the information developed as part of the Basin Plan.

3.1.10 Others

The County has developed a mailing list of organizations and citizens interested in the Muck Creek Basin planning effort. The interests range from individual landowners and citizens concerned about the LRI Landfill to water purveyors and environmental groups.

3.2 Basin Plan Stakeholder Involvement

The development of the Basin Plan has involved collection and analysis of data to determine where problems are located within the Basin. Assistance from stakeholders was solicited early in the process.

3.2.1 Basin Characterization

During development of the Basin Characterization, two sets of public meetings were held to explain the process to the residents of the Basin and to solicit issues that should be addressed in the Plan. Due to the relatively large size of the Basin two meetings were held: Graham in the eastern portion of the Basin and Roy in the western portion of the Basin. The stakeholders represented at these meetings included farmers, local businesses, citizen advocacy groups, and general citizens. The first set of meetings, held in February, 2000, were for the purpose of identifying issues for inclusion in the Basin Plan. Information collected and published in the form of a Basin Characterization Report was presented at the second set of meetings in August, 2000. At each of these meetings, County and CH2M HILL staff presented an overview of the Basin Plan process, goals, and objectives, and solicited information on general issues of concern and specific problem areas in the Muck Creek Basin. Attendees at the public meetings also helped to identify additional sources of information and specific flooding and water quality problem areas throughout the Basin. Many issues were identified at these meetings and are addressed in the Basin Plan. Some other minor issues were discussed that are beyond the scope of this project. For a detailed list of these issues, see "Appendix A, *Stakeholder Issues."*

Roy - February 10, 2000. The first public meeting held on February 10, 2000 at the Roy Public Library was planned in conjunction with the regularly scheduled monthly meeting of the Muck Creek Council. There were 27 attendees. General issues identified at the meeting included concern about future development in the Basin and impacts on the creek, creek maintenance activities, preservation of buffers along the creek, the LRI Landfill, stream flows, Fort Lewis impacts on the stream, cattle activity around streams, and disposal of used motor oil into storm drains.

Graham - February 15, 2000. The second public meeting was held on February 15, 2000 at the Rocky Ridge Elementary School in Graham. A total of 13 people were present and the meeting was well attended by members of Concerned Residents on Waste Disposal, a local advocacy group opposed to operation of the LRI landfill south of Graham. General issues discussed at this meeting included salmon spawning potential in times of low stream flow, issues associated with the LRI Landfill, loss of wetlands throughout the Basin, impacts on the stream due to growth in the Basin, general water quality and stream ecology issues, and preservation of salmon runs and fish habitat.

Roy - August 10, 2000. Approximately 20 people were in attendance. Information on the existing conditions within Muck Creek Basin were presented, including the results of the stream survey conducted during the spring. The audience had several questions regarding the "dry reach" of Muck Creek in the eastern portion of Fort Lewis. The need for riparian planting was brought out in the discussion. The topic of greatest concern at the meeting was the LRI Landfill. One citizen had a concern regarding possible environmental contamination due to an illegal methamphetamine lab that was discovered in the Basin. The long-term integrity of the landfill liner and leachate treatment system, as it related to long-term protection of water quality, was an issue to several people at the meeting.

Graham - August 31, 2000. Six interested parties attended this meeting. A resident presented information on a possible additional problem. He stated that large amounts of runoff within the northeast portion of the Basin in the vicinity of 224th Street East and Meridian, and infiltrate into the ground near the Basin boundary. This resident hypothesized that the resulting groundwater was flowing north into the Clover Creek Basin and contributing to flooding in the southern portion of that Basin. Several attendees expressed continued concern over the long-term potential of the LRI Landfill to contaminate both groundwater and the South Fork of Muck Creek.

Nisqually River Council - September 15, 2000. A presentation of the current conditions within the Muck Creek Basin was also made before the Nisqually River Council, a multiple-jurisdiction group dealing with issues within the Nisqually River Basin. This presentation was given in the Town of Yelm and included issues being covered by the Basin Plan.

The issues are brought up at these meetings are reviewed in later chapters of this Basin Plan.

3.2.2 Draft Basin Plan

During the development of the draft Basin Plan County, staff presented background information to the Graham Community Planning Board and the Graham Land Use Advisory Commission, in November and December 2002. The groups expressed interest in being kept informed about the Plan.

On January 26, 2003 Water Programs staff met with a representative of the Nisqually Indian tribe to discuss the content of the draft Basin Plan.

3.2.3 Final Basin Plan

Planning Commission--April 23, 2003
The Muck Creek Basin Plan was presented at a public hearing before the Pierce County Planning Commission. Several members of the public attended and several commented. The Planning Commission recommended approval of the Plan.

Pierce County Storm Drainage and Surface Water Management Advisory Board (SWMAB)-August 2, 2004, September 1, 2004, September 16, 2004
In August, the SWMAB was briefed on the content of the Plan. A full presentation on the Plan was given on September 1, with a follow-up presentation on September 16. The SWMAB recommended approval of the Plan to the County Council."

3.2.4 Future Stakeholder Involvement

Stakeholders have the opportunity to review the Draft Plan and SDEIS, and submit written comments. In addition, public meetings will be held during the SDEIS review period to allow opportunities for review and comment. Those comments will be addressed when the FSEIS is prepared, and the Plan will be revised as is appropriate. After the EIS review, the Plan will be presented at a public hearing before the Pierce County Planning Commission. This hearing provides another opportunity for comment on the Plan. After the Plan is approved by the Planning Commission, it is forwarded by the County Executive to the Pierce County Council, for more public review opportunities.

CHAPTER FOUR

Current Conditions

4.1 Topography and Land Forms

Located in southwest Pierce County, the Muck Creek Basin is the largest tributary, as measured by geographic area, in the Nisqually River watershed. The Basin includes Muck Creek and its three significant tributaries (Lacamas Creek, the North Fork of Muck Creek and the South Fork of Muck Creek, also known as South Creek). The Muck Creek Basin (shown in *Figure 4-1*) is approximately 93 square miles in size with elevations ranging from 140 to 960 feet. The topography of the Basin is generally flat to moderately rolling hill terrain. The only substantial relief in the Basin is the hills along the upper portion of the North Fork of Muck Creek and the canyon formed by the lower stretch of the creek as it flows into the Nisqually River. The creek flows across broad natural prairies with native grasses oaks and through local second-growth coniferous and hardwood-forested riparian habitats.

The creek and its tributaries together comprise over 50 miles of stream habitat. Muck Creek originates from a series of springs and seeps in the eastern portion of the Basin, the largest of which is Patterson Springs. The stream gradient is generally shallow with a few moderate reaches as it cuts through a canyon in its lower reaches. The creek flows through several marshes in the watershed's flat prairie areas. *Figure 4-1* shows the river miles (RM) associated with Muck Creek. The lower 14 miles of Muck Creek between RM 14 and the confluence with the Nisqually River (with the exception of a 1.1 mile stretch in the vicinity of the City of Roy) flows through Fort Lewis. Within Fort Lewis' boundaries, the creek flows across training areas and along the edge of the artillery impact area. Many creek segments within Fort Lewis have natural, intact, functioning riparian habitats, but others are in need of riparian enhancement or restoration.

Figure 4-2 shows the general land cover of the Basin. These data were obtained from 1992 LANDSAT imagery. A federal project interpreted land cover across most of the United States. This particular GIS file was obtained from Ecology. Although the data are a decade old they provide an effective visual representation of the general level of development within the Muck Creek Basin. Note that only highly intensive agriculture shows up in the agricultural category in this figure. The only agricultural land designated on *Figure 4-2* is a large dairy operation in the Lacamas Creek sub-basin. Substantial areas of pasture within the Basin have been grouped into the Natural Cover Category. *Figure 4-2* does show the low-density development within the Basin quite effectively. It also shows large areas of the Basin covered by forest. The County electronic database of 1999 ortho-photos was used to assess changes in land use which had occurred since the 1991 Plan and for layout of some of the CIP projects.

Fort Lewis is situated in the middle and lower portions of the Basin. The prominent features of Fort Lewis are large tracts of mature conifer forest and expansive prairie areas. The prairies are a relatively unique environment in the Pacific Northwest. The prairies were historically maintained by Native Americans by the use of intentionally set fires. The fires created and maintained open areas which supported camas growth. Camas is a small iris-like plant with an edible, starchy root, which the native people cooked into cakes. In the past 150 years, large

portions of the prairie areas have been invaded by fir forest. Approximately 80 percent of the prairie at Fort Lewis has been invaded by trees in the absence of maintenance fires.

4.2 Land Use and Population

4.2.1 Land Use

The Muck Creek Basin is characterized by agricultural, forest, pasture and prairie areas with low-density residential development. There are a few pockets of urban density development, particularly in the Graham area, but overall residential densities area low. The only incorporated city in the Basin is Roy. Much of the Basin is a patchwork of small (hobby) farms and ranches, interspersed with larger working cattle ranches and timber lots. Fort Lewis occupies a large percentage of the northwestern portion of the Basin.

The County has mapped the existing land uses in a GIS data set. The County Comprehensive Plan identifies future or ultimate land uses which are used to guide new development. Existing (2001) land use patterns are shown in *Figure 4-3* and summarized in *Table 4-1*. Land uses primarily consist of Residential (the majority of which is large-lot: 5 acres or larger), Open Space and Resource, and Fort Lewis. The Basin is moderately developed with a mix of rural and rural residential land uses, including low-density homes, hobby farms, farms, pasture, and prairie lands. The Basin is experiencing ongoing urbanization pressures as residential development spreads into its northern and eastern portions.

Future land uses (those uses and densities that could be permitted for new development) are also mapped in a GIS data set (Zoning). Future land uses are discussed in Section 5.6.

In addition to residential and rural development, a 320-acre landfill, owned by LRI, opened in the winter of 2000 in South Pierce County. The site includes the 168-acre landfill footprint area for waste disposal, entrance facilities, a stormwater pond, wetlands mitigation, and temporary soil stockpiles. The South Fork of Muck Creek enters the site at 304th Street, then flows in a southwesterly direction off the site under State Route 161. The landfill is discussed further in Section 3.5, *Water Quality*.

The Muck Creek Basin can be divided into four major subbasins: Muck Creek mainstem, Lacamas Creek, South Fork Muck Creek, and North Fork Muck Creek (refer to *Figure 4-12*). Impervious area data can be found in “Appendix J”. Estimates of existing impervious surface for each subbasin were derived from the land use data, as shown in *Table 4-1*. Impervious percentages were taken from the *Guidance for Basin Planning* (URS, 2000), except as noted in *Table 4-1*. The plat maps available from the County Assessor were used to break down the lot sizes of the residential categories. Under the Residential category, the lot sizes of individual residential parcels were first aggregated by lot size (quarter-acre, third-acre, half-acre, etc.), and percent-impervious was assigned in accordance with the guidance document.

The Muck Creek main stem subbasin averages approximately 6.3 percent impervious. The Lacamas Creek subbasin also averages 6.3 percent impervious. The South Fork Muck Creek subbasin averages 6.8 percent impervious, while the North Fork Muck Creek subbasin has the highest amount of impervious area, averaging 10.2 percent, due largely to the concentration of population in the Graham area. The overall impervious area for the Muck Creek Basin is 7.3 percent.

Fort Lewis W.Q. MUCKCR03

Basin Study Stream Gage at Roy

Fort Lewis W.Q. MUCKCR01

Exeter Springs

Nisqually Tribe W.Q. RM 0.5

Long Term Monitoring Well AFC-086

Johnson Springs

Muck Creek

Chambers Lake

Muck Lake

Roy

Lacamas

Fort Lewis W.Q. MUCKCR02

Nisqually Tribe W.Q. RM 6.3

Fort Lewis W.Q. MUCKCR05

Basin Study Stream Gage on the North Fork

Fort Lewis W.Q. MUCKCR06

N Fork Muck Cr

S Fork Muck

Patterson Springs

Long Term Monitoring Well AFC-094

8TH AVE

24TH AVE

8TH AVE S

70TH AVE E

MERIDIAN E

MOUNTAIN HWY E (SR 165)

KAPOWSIN HWY

KINSMAN RD E

CHRISTENSEN

EATONVILLE CUTOFF

SR 161 E

SR 702 S

HART'S LAKE LOOP RD S

224TH ST E

246TH ST

264TH S

288TH ST E

288TH ST

298TH ST

320TH ST E

336TH ST S

340TH ST E

Muck Creek Basin Plan
Pierce County, Washington

LEGEND

- Spring
- Original Basin Boundary

Station Type
- Water Quality Sample Points
- Stream Flow Gaging
- 5 River Mile (RM)
- Long-Term Monitoring Well

- Major Roads
- Railroads
- Stream
- Water Body
- Sections
- Fort Lewis
- City

Wetlands
- Wetlands

N W E S

3000 0 3000 Feet

1:72000

PIERCE COUNTY

CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

Figure 4-1
Muck Creek Basin
Basin Map

Wetland Data Source: National Wetlands Inventory augmented with local wetland surveys.

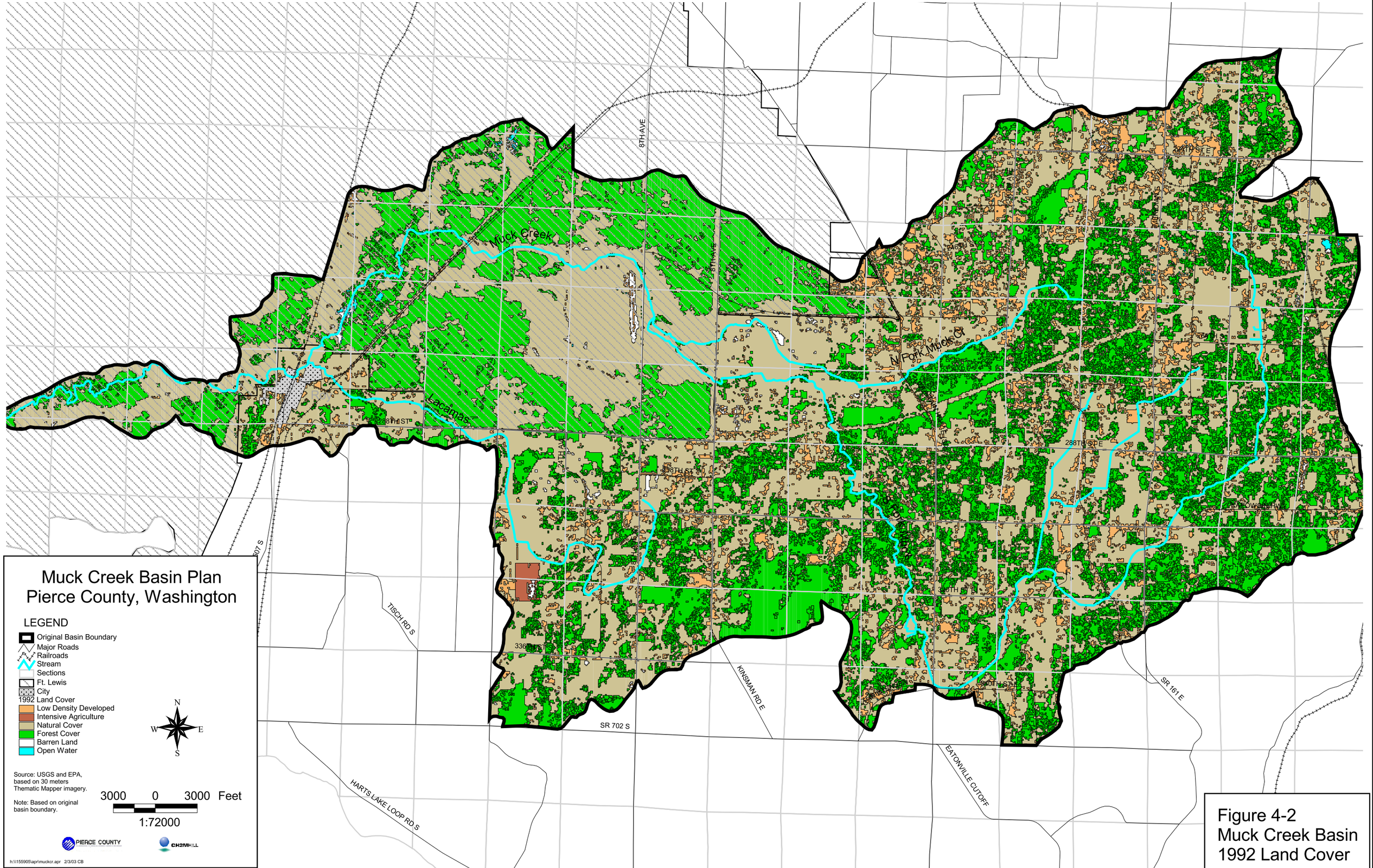


Figure 4-2
Muck Creek Basin
1992 Land Cover

Muck Creek Basin Plan
Pierce County, Washington

LEGEND

- Original Basin Boundary
- Major Roads
- Railroads
- Stream
- Water Body
- Township and Range
- Sections
- Ft. Lewis
- City

Existing Land Use

- Residential
- Commercial/Service
- Education
- Public Facilities
- Industrial
- Transportation/Communication/Utilities
- Open Space/Resource Lands

N W E S

3000 0 3000 Feet

1:72000

PIERCE COUNTY CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

T18N T17N R2E R3E R4E

Muck Creek Chambers Lake Muck Lake Lacamas

8TH AVE 8TH AVE S 24TH AVE 24TH AVE E 70TH AVE E MERIDIAN E

288TH ST 288TH ST E 298TH ST 304TH ST E 320TH ST E 340TH ST E 264TH ST

N Fork Muck Cr S Fork Muck

TISCH RD S 336TH ST S KINSMAN RD E CHRISTENSEN RD E

SR 702 S SR 161 E EATONVILLE CUTOFF

HARTS LAKE LOOP RD S

MOUNTAIN HWY E (SR 7) KAPOWSIN HWY

Figure 4-3
Muck Creek Basin
Existing Land Use
(10/01)

Table 4-1 Land Use Patterns

Land Use Category	Acres	Percentage of Basin[1]	Percent Impervious Surface
Residential	19,022	32.1	
Single Family			See text
Multi-Family			50%
Commercial/Service	293	0.5	83%
Industrial	36	0.1	67%
Transportation/Communication/ Utilities	299	0.5	5%[2]
Education	414	0.7	25%
Public Facilities	199	0.3	47%
Open Space/Resource Lands/Vacant	21,978	37.0	5%[2]
Other	1,042	1.7	20%[3]
Roads	1,228	2.1	51%
Fort Lewis	14,867	25.0	5%[2]

1 Does not add to 100 percent.
2 Estimated from general review of Basin aerial photos.
3 Estimate; includes lands that are partially developed.

4.2.2 Current Population

The Muck Creek Basin is largely rural in nature. The northwestern quarter of the Basin lies within Fort Lewis and has virtually no permanent population. Population centers include the community of Graham in the northeast portion of the Basin and the City of Roy in the west.

The population estimate of the Muck Creek Basin for the year 1990 was prepared using census block group data from Pierce County GIS files. The 1990 population figures were estimated from the 25 individual census block groups located within the Basin boundaries. Population estimates for the year 2000 were prepared using 2000 census tract data from the U.S. Census Bureau's web site. The 2000 population figures were estimated from the 11 individual census tracts located within the Muck Creek Basin boundaries. Population figures for each census tract were calculated in proportion to the area of the Basin within each tract.

- 1990: 15,470
- 2000: 23,435

These figures indicate a population increase of 51 percent. For comparison, Pierce County population increased by 155,000 to 701,000, a nearly 20 percent increase. Thus, the Muck Creek population grew at more than twice the rate of Pierce County for the same time frame. Maps and a listing of the 1990 and 2000 census block groups and tracts within the Muck Creek Basin are shown in "Appendix I". Future population projections for the Basin can be found in Section 5.6.

4.3 Soils

The surficial soils in the Basin, shown in *Figure 4-4*, consist almost exclusively of two associations, Kapowsin and Spanaway. Kapowsin Soils formed in glacial till. They are underlain at a depth ranging from 2 feet to more than 5 feet by an impermeable till layer.

Perched groundwater and areas of standing water can form during the wetter months. The second soil association, Spanaway Soils, formed in glacial outwash. Approximately half of the Muck Creek stream system flows across these permeable deposits and loses large amounts of flow to the regional groundwater during most of the year. These soils are rapidly draining and are underlain by highly permeable gravel deposits. These soils have very little surface runoff and, except during periods of high local groundwater levels, will rapidly infiltrate surface water. These two contrasting conditions have a marked effect upon hydrology. For instance, existing inventory data indicate that wetlands cover 10 percent of the area overlain by Kapowsin Soils. In contrast wetlands cover just 2 percent of the more freely draining Spanaway Soils. The majority of Muck Creek, North Fork, and one-third of South Creek are Spanaway association. The upper two-thirds of South Creek, primarily all of Lacamas Creek, and the upper one-quarter of North Creek are Kapowsin association.

The glacial till and outwash are derived from Vashon Drift which was deposited during the Vashon Stade of the Fraser glaciation. The Drift consists of predominantly gravels and sands with some local deposits of silt and clay (Engle, 1997).

Walters and Kimmel (1968) developed a map of the geologic deposits within central Pierce County, covering the Muck Creek Basin. Information from this report is adapted for *Figure 4-5* to illustrate the various geologic deposits through which the stream system flows. The surficial geology of the Muck Creek Basin shows a distinct pattern. The eastern and southern portions of the Basin are overlain primarily by glacial till deposits. These deposits are reflected on *Figure 4-4a* as “Hydrologic Soil” groups. Hydrologic soil types are indicative of the drainage capacity of a soil. The designations are representative of a range of soil permeablility. An “A” soil would be the most very permeable, resulting in the least stormwater runoff, while a “D” soil would be impermeable.

There are isolated peat deposits, some quite large in areal extent. Both types of deposits are relatively impermeable and streams flowing over them would typically lose little water. The stream channels in these areas also pass through alluvial deposits. Alluvium can be a source of water to a stream if the groundwater table is near the surface. It can also serve as a sink if the groundwater table is low.

Much of the middle portion of the South Fork (RM 3-10) passes through recessional outwash. This material can be very permeable. Where the water table is below the creek bottom, the South Fork may lose flow.

The lower portions of Lacamas Creek (RM 0-3), the lower South Fork of Muck Creek (RM 0-3), and most of the mainstem and lower North Fork of Muck Creek (RM 1-14) pass through Steilacoom Gravel. This formation consists largely of gravel and cobbles. It is highly infiltrative and can transmit large quantities to groundwater. Where the water table is not near the surface, streams flowing across the formation can be expected to lose flow.

4.4 Natural and Constructed Drainage System

This section begins with an overview of Muck Creek’s natural drainage system, followed by a discussion of the flow characteristics of the stream and its tributaries. This section concludes with a brief discussion of the constructed drainage features and infrastructure, including water supply systems.

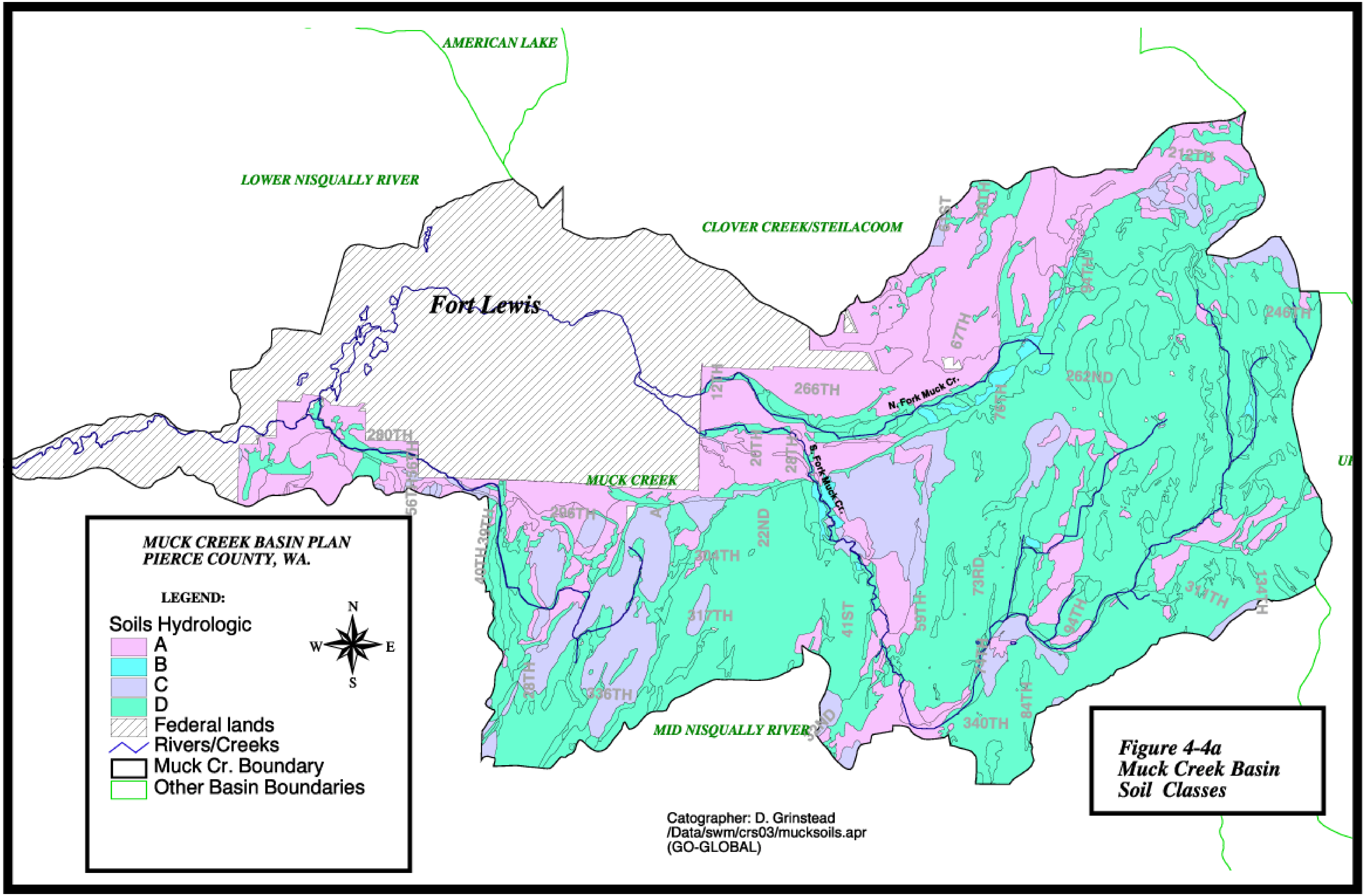


Figure 4-4a
Muck Creek Basin
Soil Classes

Catographer: D. Grinstead
/Data/swm/crs03/mucksoils.apr
(GO-GLOBAL)

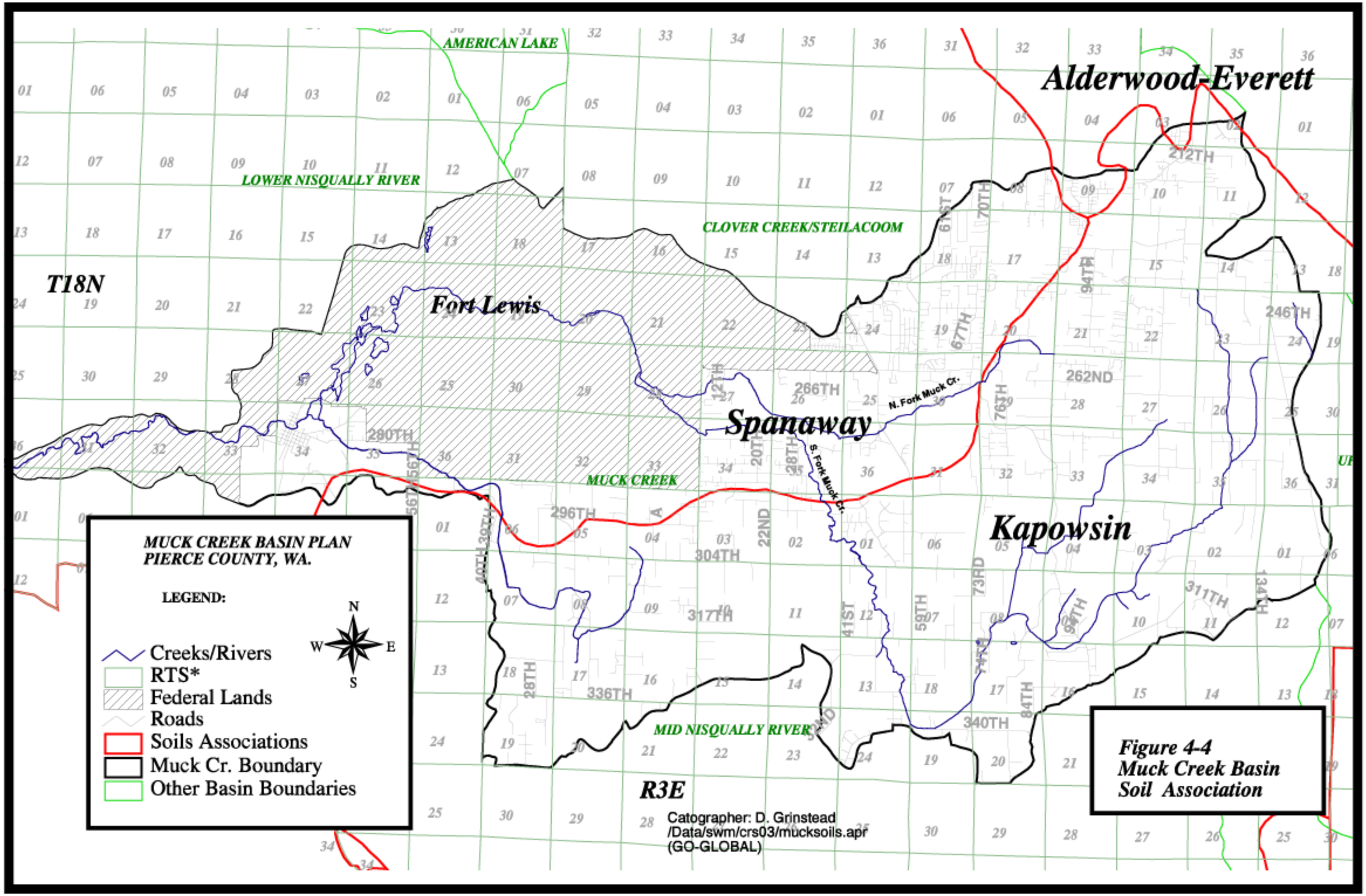


Figure 4-4
Muck Creek Basin
Soil Association

Muck Creek Basin Plan
Pierce County, Washington

LEGEND

- Original Basin Boundary

Surficial Deposits

1. Qs- Steilacoom Gravel
2. Qvr- Recessional Outwash
3. Qa- Alluvium
4. Qvt- Till
5. Qp- Peat

- Major Roads
- Railroads
- Water Body
- Township and Range
- Sections
- Ft. Lewis
- City

N W E S

3000 0 3000 Feet

1:72000

PIERCE COUNTY

CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

T18N

T17N

R2E

R3E

R4E

8TH AVE

8TH AVE S

24TH AVE

70TH AVE E

MERIDIAN E

224TH ST E

246TH ST

264TH S

288TH ST

288TH ST E

298TH ST

320TH ST E

336TH ST S

340TH ST E

SR 702 S

KAPOWSIN HWY

MOUNTAIN HWY E (SR-7)

TISCH RD S

HARTS LAKE LOOP RD S

KINSMAN RD E

CHRISTENSEN

EATONVILLE CUTOFF

SR 161 E

Figure 4-5
Muck Creek Basin
Surficial Deposits Along the Stream Channels

4.4.1 Natural Drainage System

Muck Creek originates as two major forks (*Figure 4-1*). The North Fork begins west of the community of Graham. It flows westerly, meeting with the second major fork the South Fork) in the north-central portion of the Basin. The South Fork originates south of Graham and flows southwest to the south-central portion of the Basin. At this point it turns sharply northwest, flowing to meet the North Fork. Below the convergence of the two forks, the Main Stem of Muck Creek flows westerly through Fort Lewis and the City of Roy. Lacamas Creek converges with Muck Creek in Roy. Muck Creek empties into the Nisqually River, about 10 miles upstream of the river's mouth. The Muck Creek Basin encompasses approximately 93 square miles, about one-seventh of the entire Nisqually River Watershed. Except for a short stretch of stream through Roy, the entire main stem of Muck Creek lies within Fort Lewis in an undeveloped portion of the Base that is used primarily for troop maneuvers. The remaining portion of the Basin is mostly rural in nature, containing numerous farms and extensive tracts of second growth forest.

Early in this study the Basin boundary, as contained in the County's GIS database, was carefully reviewed using the 5-foot topography available for the study area. In most cases the boundary line was accurate. However, the Basin boundary along Mountain Highway in the south-central portion of the Basin and also along the east-central boundary may need to be adjusted. The potential boundary adjustments are shown on the figure in "Appendix B." The revised boundaries, if adopted by the County, would increase the Basin area by 2.3 square miles (to 92.8 square miles) or 2.6 percent. Revision of Basin boundaries will involve a coordinated review of all adjacent affected basins.

The North Fork and South Fork are two tributaries of Muck Creek that drain the eastern two-thirds of the Basin and converge in the central portion of the Basin (*Figure 4-1*). The drainage area of the North Fork is 20.5 square miles and its length is 7 miles. The South Fork drainage area is approximately 36.6 square miles in area and the length along its longest tributary is 17 miles. The Main Stem of Muck Creek (20.6 square miles) extends nearly 14 miles below the convergence of the North and the South forks. A third tributary, Lacamas Creek (15.2 square-mile drainage area) has a length of 7 miles and intersects the Main Stem of Muck Creek in Roy.

The North Fork is a perennial stream whose headwaters are Patterson Springs. Much of the North Fork was extensively channelized decades ago. The upper portion of the South Fork splits into a northerly branch and a southerly branch. Most of the South Fork can go dry during the late summer and early fall months. Long-term flow records for Muck Creek at Roy indicate that the stream is commonly dry at this location, as well. Upstream of Roy, Muck Creek flows through a series of wetlands and lakes, the largest of which is Chambers Lake. The other lakes include Muck Lake and Shaver Lake. Flow from several springs, including Nixon and Johnson Springs, feeds into the creek upstream of Roy. Downstream of Roy, the creek passes through large wetlands and then enters a ravine for the final 4 miles to its mouth at the Nisqually River. In this final stretch, it receives inflow from Exeter Springs.

4.4.2 Streamflow Characteristics

Previous Flow Monitoring: Continuous discharge stream flow measurements were taken at a U.S. Geological Survey (USGS) gauging station located at a railroad bridge crossing Muck Creek in Roy (Station 12090200). Flow monitoring occurred from 1956 to 1971. The data show that there were periods of no flow in the creek for 10 of the 15 years of record. Over the period of record, zero flow was recorded 9.1 percent of the days (Pearson and Dion, 1979). The majority of the no-flow days occurred between August and November. The longest period with zero flow occurred between July 24 and December 7, 1956 (136 days). A peak flow of 600

cubic feet per second (cfs) was recorded on January 21, 1971. Average flow during this period was 64 cfs (45,191 acre-ft/year). If spread evenly across the Basin, this would amount to a runoff depth of 9.8 inches, or about 24 percent of the rainfall (as recorded at nearby Fort Lewis) over the Basin.

Other portions of Muck Creek also go dry during the summer and early fall months of many years. Muck Creek consists of gaining and losing sections. The creek is considered "losing" when the river stage is higher than the water table and recharge to the aquifer occurs. The creek is considered is "gaining" when the river stage is lower than the water table and the aquifer releases water to the creek. The creek loses all flow and goes dry because of geologic conditions in the Basin, but human activities may have intensified the losses to groundwater (Engle, 1997). Spot flow measurements included in "Appendix H" indicate zero flow in the creek at Roy as far back as September 1949 (unpublished flow data, Washington Department of Ecology).

Engle (1997) conducted a limited investigation and determined that major flow losses from the creek were occurring along the Main Stem and the lower North Fork between RM 11 of the Mainstem and RM 1.5 of the North Fork (*Figure 4-1*). This phenomenon was confirmed during a field reconnaissance by staff from Ecology, who observed in August 1999 that the North Fork had flow but, after its intersection with the South Fork, the creek had no flow again until Roy (Sinclair 1999, personal communication). A tour of the Basin conducted as part of this Basin Plan (11/2/99) revealed that most of the South Fork was dry, as was the main stem of Muck Creek through Roy (see *Figure 4-6*). However, during a Basin reconnaissance a month later (12/2/99) flow had returned to these sections of the creek.

During periods of low flow in Muck Creek, a small flow is contributed from Lacamas Creek, which enters Muck Creek a short distance above Roy. But this flow quickly seeps through the stream bottom of Muck Creek. In contrast, the flow in the North Fork remains perennial, and generally remains about 3 cfs during the summer period.

Flow loss from portions of the streambed can be quite dramatic. On May 5, 2000, the flow in the Main Stem at a stream ford approximately one-quarter mile upstream Highway 507 was visually estimated to be greater than 20 cfs. The stream channel was traversed by foot, downstream toward the highway. In less than one-quarter mile, prior to reaching the highway, the flow completely disappeared and the channel was dry, the flow having seeped into the alluvium over this short distance. Staff at Fort Lewis have indicated that over the past 3 to 5 years, the stream has commonly gone dry upstream to about RM 11-12 (Clouse 2000, personal communication).

Lacamas Creek, which drains the southern portion of the Basin, has perennial flow during most years, but also occasionally goes dry. Miscellaneous stream flow data have been taken at Lacamas Creek east of Roy from July 5, 1949 to November 11, 1989. There was no flow in the creek on only 5 of the 37 sampling dates, all of which occurred in July-October 1986 and June 1987 (unpublished flow data, Washington Department of Ecology). Lacamas Creek generally flows the year-round, entering Muck Creek a short distance upstream of Roy. Frequently during the summer, flow from this creek is the only source of water to Muck Creek along this portion of its channel.

The 2001 Water Year (October, 2000 through September, 2001) was an unusually dry year with total rainfall only 78 percent of the average annual rainfall of 40 inches. Informal visual observations were made of Muck Creek at the Highway 507 crossing, north of Roy, every month or two during this period. This location is downstream of the point on Fort Lewis where Muck Creek typically goes dry during the summer. This crossing was dry by early May, 2000. No

Muck Creek Basin Plan
Pierce County, Washington

LEGEND

- Original Basin Boundary
- Major Roads

Stream Flow-11/04/99

- Dry
- Flowing
- Not Observed
- Water Body
- Sections
- Ft. Lewis

N / W / E / S

3000 0 3000 Feet

1:72000

PIERCE COUNTY

CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

Muck Creek

Chambers Lake

Muck Lake

Lacamas

N Fork Muck Cr

S Fork Muck

8TH AVE

24TH AVE

8TH AVE S

70TH AVE E

MERIDIAN E

MOUNTAIN HWY E (SR-7)

224TH ST E

246TH ST

264TH S

288TH ST

288TH ST E

298TH ST

KAPOWSIN HWY

320TH ST E

340TH ST E

336TH ST S

SR 702 S

TISCH RD S

KINSMAN RD E

CHRISTENSEN

SR 161 E

EATONVILLE CUTOFF

HARTS LAKE LOOP RD S

Figure 4-6
Flow Pattern Observed in the
Muck Creek Basin November 4, 1999

flow was observed at this crossing between May, 2000 and late fall of 2001 (although there is evidence in the form of one, small, stranded fish at the crossing that flow occurred briefly at least once during this period). It was also reported that the mouth of Muck Creek had little or no flow through most of the winter of 2000-01, a rather rare occurrence (Clouse 2002, personal communication).

Visual observations of the lower half of the Muck Creek system stream have been made at 22 locations as part of an on-going study of streams within Fort Lewis (Herrera Environmental Consultants, unpublished data, 2002). Observations made on September 19 and December 13, 2000 showed the same pattern (*Figure 4-7*). There was no flow in the lower portion of the South Fork. The North Fork and main stem had flow to a point about one mile west of 8th Ave. S. Muck Creek was dry for several miles on either side of Highway 507. Discharges from wetlands and lakes within the Fort upstream and downstream of Roy apparently provided flow to the creek . [1] A considerable length of the middle stream canyon below Roy was dry. However, flow was observed at the mouth, likely due to discharge from Exeter Springs, located a short distance upstream.

It is evident that major portions of the stream system go dry for long periods of time, particularly during drier-than-normal years.

Current Flow Monitoring: As part of the current Basin study, two recording temperature and flow gages were installed and have been operating since March 2000. As shown in *Figure 4-1*, one is located along Muck Creek in Roy, a short distance upstream of the old USGS gage. The second was installed on the North Fork, just downstream of the crossing of 8th Avenue East.

Figures 4-8a and 4-8b show the flows at the two stream flow monitoring sites at Roy and North Fork at 8th Avenue E, respectively. During 2001 there are some gaps in the data due to sensor damage or other problems. The highest recorded flow (440 cfs at Roy) was at the time of gage installation in late March, 2000. This flow slowly declined over the next three months to 20 cfs and then dropped below 1 cfs by late June. There was essentially no flow at the Roy site from mid-July through mid-October. During this period occasional rainfalls as high as 0.6 inches failed to generate flow in the stream. Between October 8 and 18, several storms generating a total of 3.0 inches of rain finally were sufficient to generate flow again. However, winter flows at Roy did not rise above 10 cfs until late January, 2001. The flows remained in the 40-60 cfs range from April through early June. They once again declined rapidly to zero flow. There was little or no flow during the rest of the summer and most of the fall. The flow increased above 70 cfs in late November, 2001 following a series of intense storms that month.

Figure 4-8a also shows a plot of the average daily flows for the 15-year period of USGS flow records. This plot shows low flows between mid-July and early November. Flow then builds steadily to a peak which is well over 200 cfs in late January. This is followed by a steady decline to low flow conditions in the summer. At the start of the current flow monitoring effort in March, 2000, spring flows were considerably higher than average. Flows for both 2000 and 2001 followed the long-term average for April and May until they dropped suddenly in June, where they remained at or near zero beyond the end of the water year. Although part of the record is missing for the spring of 2001, the influence of this drought year is reflected in the relatively low the winter flows recorded through the end of February.

[1] However, the recorded flow at the Roy gage was essentially zero on the September 19 date.

The peak flow recorded on the North Fork at 8th Ave. E was 48 cfs in mid-April, 2000 (*Figure 4-8b*). Flow generally varied between 10-20 cfs until mid-June. It then declined to between 2-4 cfs until mid-November and it then varied between 5-10 cfs through mid-April, 2001. Although the data between mid-April to late June is sketchy, flows appear to remain between 10-15 cfs. Flow then declined to around 3 cfs, where it remained through at least late September.

The continuous flow data can be plotted with daily rainfall data from nearby Fort Lewis (Appendix H). The data show that there is a consistent time lag of about 2 days between the larger storms (greater than one-half inch in 24 hours) and the flow response in the middle portion of the North Fork. In contrast that there is a consistent time lag of about 4 days between the larger storms and a peak flow response in the stream at Roy. This is difference in lag times is likely due to Roy's lower position in the Basin and to the influence of the intervening lakes and large wetlands upstream of Roy on Fort Lewis.

4.4.3 Stream-Groundwater Exchange

During 2000 and 2001 the Department of Ecology carried out a study of stream and groundwater interactions along Muck Creek and its tributaries (Sinclair, 2001). The water levels in 15 wells were monitored at monthly intervals. In addition shallow observation wells, known as piezometers, were placed in the beds of streams at 13 locations throughout the Muck Creek Basin. An additional 6 piezometers were installed in streams flowing through Fort Lewis late in this study. Water levels were measured, monthly, in these piezometers to determine whether the stream was gaining or losing water through the streambed at these locations. On three occasions following extended periods of dry weather (June and September, 2000 and February, 2001), stream flow was measured at a series of locations along the streams to determine addition or depletion of flow through the streambed.

The study reached a number of conclusions. Average annual groundwater recharge in the Basin was estimated to be on the order of 120,000 acre-feet. Total stream recharge to the groundwater was calculated to vary from 3,620 to 20,270 acre-ft/year across the three dates of intensive stream flow measurements. Given the drought conditions that persisted over most of the study period, it was suggested that the long-term stream recharge rate is probably on the order of 20,000 acre-feet per year. Therefore, stream recharge appears to provide about 15 percent of the total annual groundwater recharge from the Basin.

The flow behavior of each of the major stream reaches was reviewed in the Sinclair Report. Lacamas Creek was the one of the few streams with perennial (year-round) flow. At times during the mid to late summer and early fall, Lacamas Creek provides the only flow in Muck Creek through Roy, although this flow often seeps into the stream channel within a short distance downstream of the juncture of Muck and Lacamas creeks.

The upper half of the North Fork of Muck Creek typically gains flow while the lower half loses flow. However, flow from the North Fork maintains a perennial stream for a distance of about one mile below the junction of the North Fork and the South Fork. Below this junction, the highest loss rates of flow in the Basin were recorded, up to 29 cfs per mile of stream in February, 2001. Depending upon the amount of annual rainfall, the stream will go dry at varying distances (typically about 2 miles) downstream of 8th Avenue South. It will remain dry to a point about one-half mile downstream from Roy (a distance of about 6 miles), where outflow from wetlands and several springs re-establishes perennial flow conditions in most years. Most of

Muck Creek

Chambers Lake

Muck Lake

Note: The stream was dry at Roy on September 19

Lacamas

8TH AVE

8TH AVE

24TH AVE

8TH AVE S

70TH AVE E

MERIDIAN E

224TH ST E

246TH ST

264TH S

N Fork Muck Cr

MOUNTAIN HWY E (SR-7)

288TH ST

288TH ST E

298TH ST

S Fork Muck

KAPOWSIN HWY

320TH ST E

TISCH RD S

336TH ST S

KINSMAN RD E

CHRISTENSEN

340TH ST E

SR 161 E

SR 702 S

EATONVILLE CUTOFF

HARTS LAKE LOOP RD S

Muck Creek Basin Plan
Pierce County, Washington

LEGEND

- Original Basin Boundary
- Major Roads

Stream Flow-09/19/00 and 12/13/00

- Dry
- Flowing
- Not Observed
- Water Body
- Sections
- Ft. Lewis

N
W E
S

3000 0 3000 Feet

1:72000

PIERCE COUNTY

CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

Figure 4-7
Flow Pattern Observed in the Lower Muck Creek System September 19 and December 13, 2000

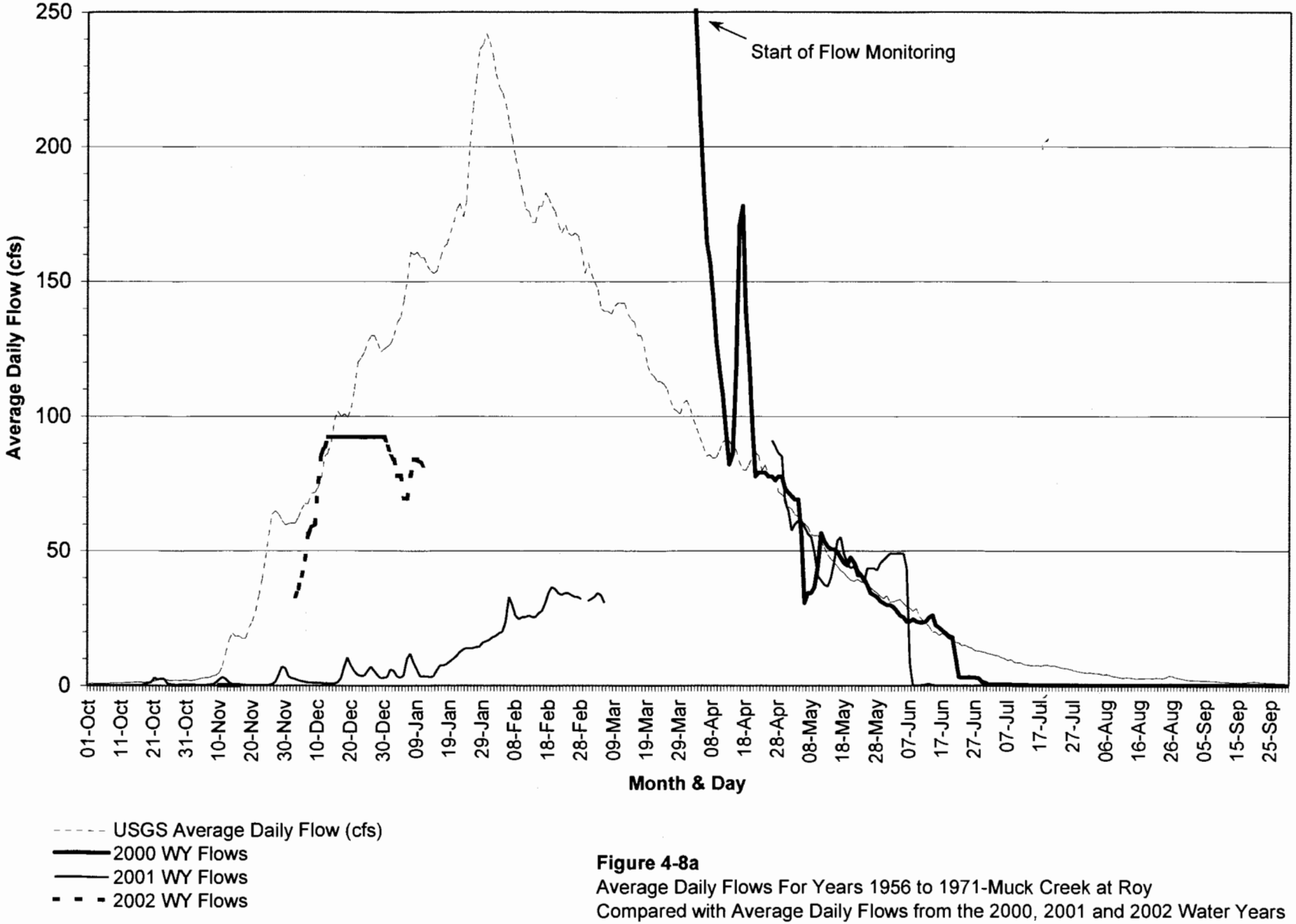


Figure 4-8a
Average Daily Flows For Years 1956 to 1971-Muck Creek at Roy
Compared with Average Daily Flows from the 2000, 2001 and 2002 Water Years

Figure 4_8a.xlsMuck Creek Ave Daily Flow Chart

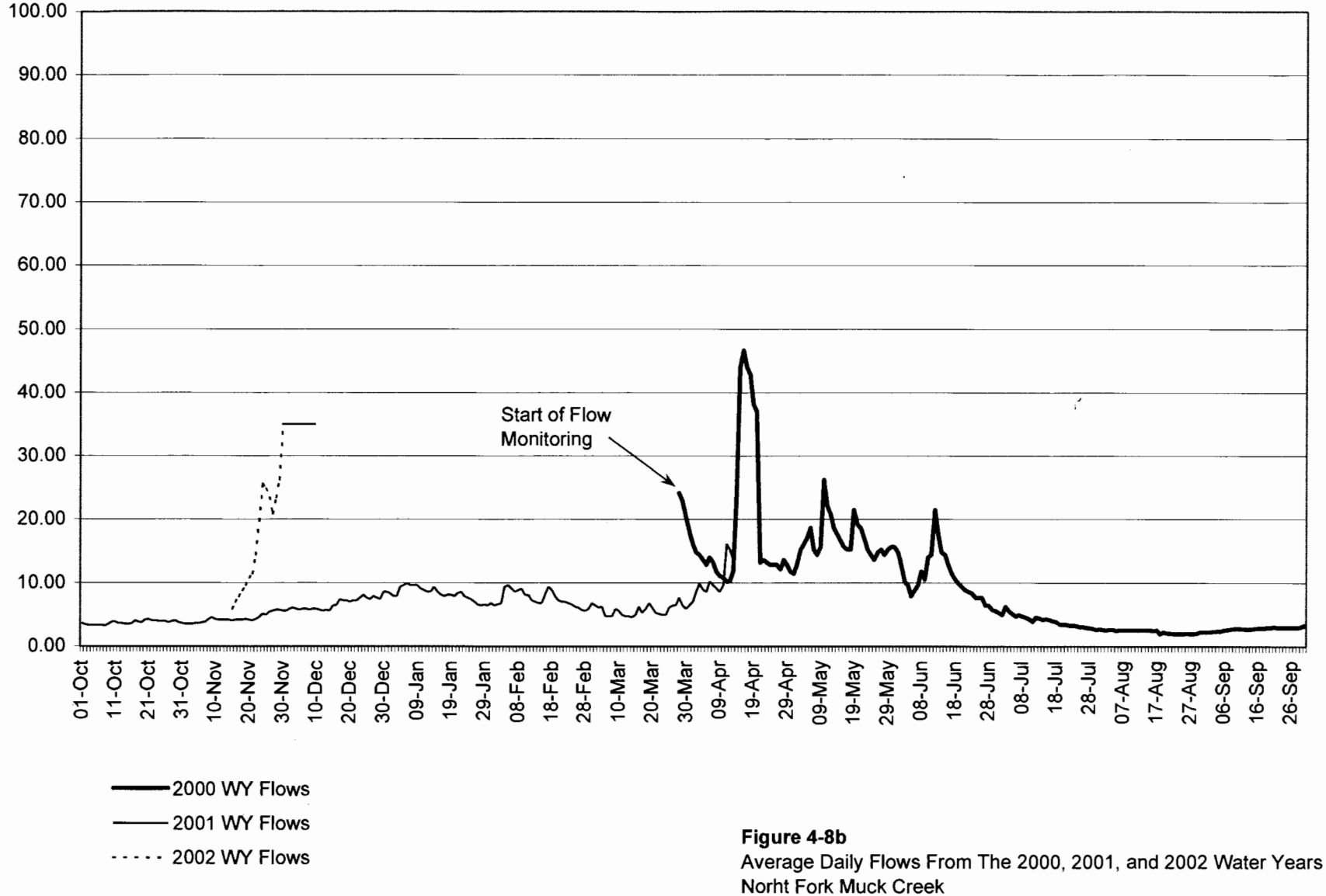


Figure 4-8b
Average Daily Flows From The 2000, 2001, and 2002 Water Years
Norht Fork Muck Creek

the middle and lower sections of the South Fork also lose flow to the groundwater. Except for isolated pools, this stream typically goes dry every year. There is a 2-mile stretch of this stream (starting at about 5 miles above its junction with the North Fork of Muck Creek) where groundwater seepage into the creek results in perennial flow along this short stretch.

4.4.4 Regional Groundwater

There are two wells within the Muck Creek Basin which have been monitored for many years by the U.S. Geological Survey and therefore have long-term records of groundwater level: Well AFC086 in Roy and Well AFC094 northeast of Graham. Their locations are shown on *Figure 4-1. Figure 4-9a* shows water levels measured since the 1940s. Although there have been only limited measurements since 1974, neither well shows any trend of increasing or decreasing water levels over the past 50 years. Both wells show annual water level fluctuations which are typically 5-7 feet. Water level in the Roy well has varied from 4 to 12 feet below ground while the water level at the Graham well has varied from 50 to 61 feet below ground.

From a topographic standpoint, most of Graham lies within the Muck Creek Basin. Despite opposing topography (the land rises north of 224th), there are indications that water infiltrating in the Graham area flows north and surfaces in the Clover Creek area, north of the Muck Creek Basin boundary. The Sinclair Study (2001), reviewed groundwater movement across the entire Muck Creek Basin. The basin-level groundwater contour data developed by this study did indicate likely groundwater movement from the Graham area west and northwest to the Clover Creek Basin.

In the mid-1980s an extensive report on groundwater conditions in the Clover/Chambers Creek area was prepared (Brown and Caldwell 1985). Although this study focused on a large area north of the Muck Creek Basin, the southeastern portion of that study area extends as far south as 240th in the Graham area. Potentiometric (groundwater elevation) maps were produced for both the shallow and the deep groundwater system. It was acknowledged that these maps were conservatively developed in the sense that they are drawn to encompass the maximum amount of area justified by the data (Brown and Caldwell 1990). Groundwater flow can be inferred to flow perpendicular to the potentiometric lines. *Figure 4-9b* indicates that the groundwater divide is located from one-half to one and one-half miles south of 224th Street E. Groundwater north of this divide appears to move northwest, into the Clover/Chambers Basin. Much of Graham appears to fall within the Clover/Chambers Creek groundwater influence area (*Figure 4-9b*). It is important to note that the Brown and Caldwell Study concentrated upon the Clover/Chambers Basin and that the Graham Area was an outlying portion of that study. The study was also performed about 15 years ago. A groundwater monitoring program focused in the Graham area would need to be undertaken to better define the issue of groundwater movement.

The outer boundaries of this groundwater area may be somewhat suspect. For instance, the boundary passes through or near Patterson Springs. This is the major source of flow for the upper portion of the North Fork of Muck Creek and would clearly seem to be well within Muck Creek groundwater influence area. Nonetheless, this is the most detailed available map of groundwater movement in the Graham area.

4.4.5 Constructed Drainage System

Numerous culverts and bridges have been constructed throughout the Basin at the County road and state highway crossings. Due to its rural nature, relatively few large-scale drainage structures have been constructed in the Basin. Portions of Lacamas Creek and the North Fork of the South Fork have highly linear sections, obviously channelized in the past. However the great majority of the creek and its tributaries have not been re-channeled in recent years or rip-rapped. Some ditching of side drainages in the farmed areas is evident, however.

There are several medium-sized lakes within Fort Lewis. Chambers Lake was formed by damming a wetland area in 1967. In the late 1980s, the dam was reconstructed to incorporate a fish passage structure. The dam can control lake level fluctuations through about 5 vertical feet. The lake covers 80 acres and has a storage volume of 300 acre-ft (Sinclair, 2001). The operation of the outlet to Chambers Lake can have a substantial effect upon downstream flow in Muck Creek at certain times of the year (refer to Section 5.2). North of Chambers Lake is Johnson Lake. It was formed when a small dam was constructed in 1976. A constructed lake lies within the eastern portion of the Basin, between 288th and 304th streets. Holder Ski Pond is a long, narrow lake constructed in 1986. It lies along one of the small tributaries to the South Fork and is about 11 acres in size.

Pierce County recently performed an inventory of all County-maintained drainage facilities. The facilities were located using a Global Positioning System (GPS) and input into a Geographical Information System (GIS). As part of that inventory, all drainage facilities within the Muck Creek Basin were identified. There are 619 catch basins, 176 dry wells, and 239 miles of ditches within the Basin. *Table 4-2* lists the distribution of pipes and culverts within the Basin.

Table 4-2 Inventory of Storm Pipes and Culverts

Size (Diameter)	12"	18"	24"	36"	48"	*Other	< 12"	> 48"	Total
Pipes: Length (mi)	6.3	0.7	0.3	0.3	0.1	2.2	1.8	0.0	9.9
Culverts: Length (mi)	17.3	2.0	0.6	0.2	0.1	3.3	2.5	0.4	23.5

*Pipes or Culverts that did not fall within 12”, 18”, 24”, 36”, 48”, < 12”, or > 48” categories.

Over the past decade, federal, state and county regulations have required the installation of stormwater management systems for new development. As a result, stormwater infiltration and detention ponds have been constructed within the Basin to reduce flood hazards and protect water quality. Perhaps the largest of these is the stormwater treatment and detention pond at the LRI Landfill in the eastern portion of the Basin. This 4-acre pond treats and detains surface runoff from the landfill, releasing it to the South Fork of Muck Creek, just upstream of its crossing of Mountain Highway.

4.4.6 Water Systems

There are several dozen water supply systems within the Basin. All of them draw their water supply from wells. Most of these systems are small, serving less than 15 customers. The two largest systems serve the Roy and the Graham areas and have developed water system plans which contain data on municipal water use. The City of Roy operates its own water supply. The system was installed in 1989, in part to remedy contamination of several private wells due to agricultural chemicals (Jacobs 2000, personal communication). Two wells produce water to

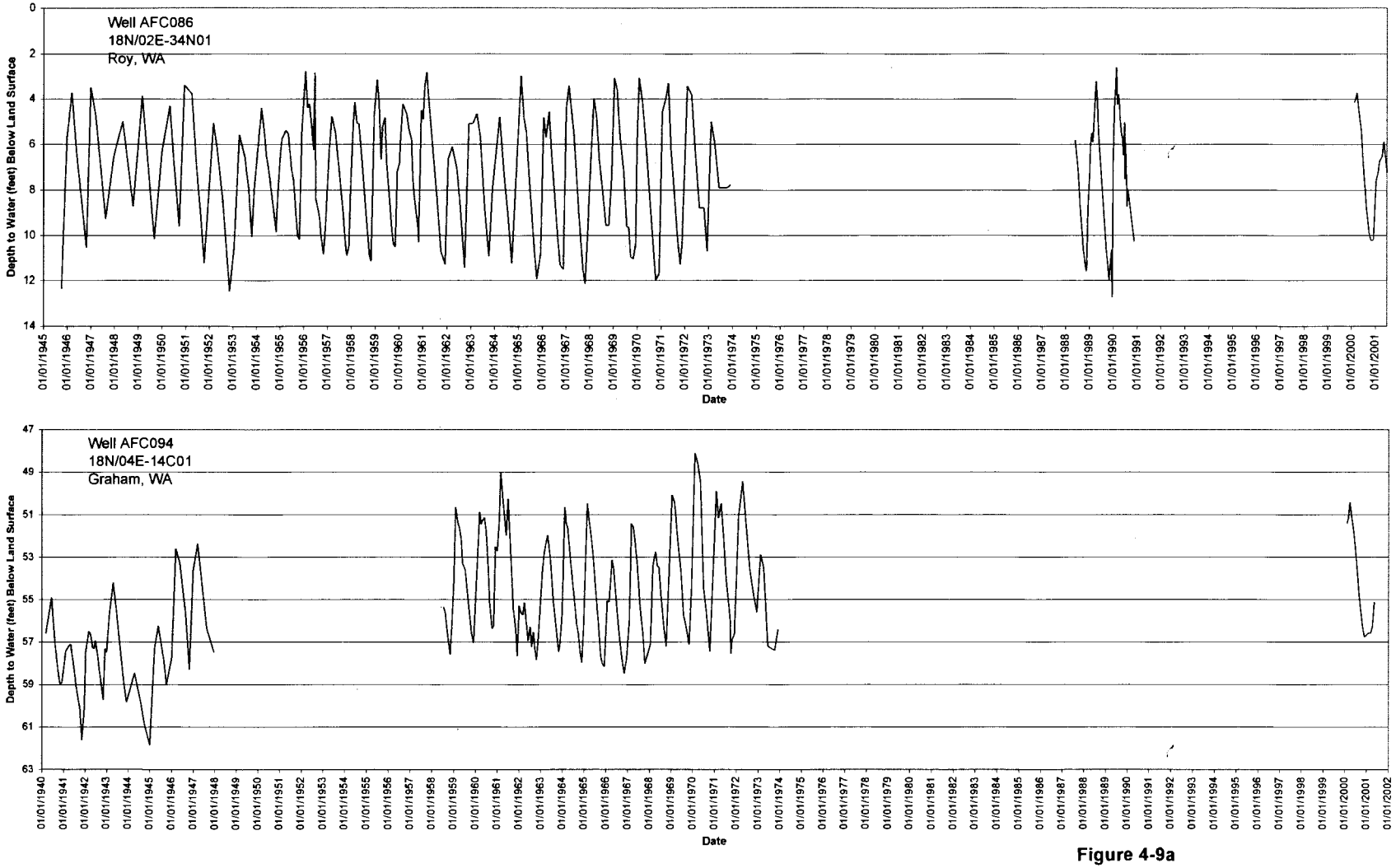
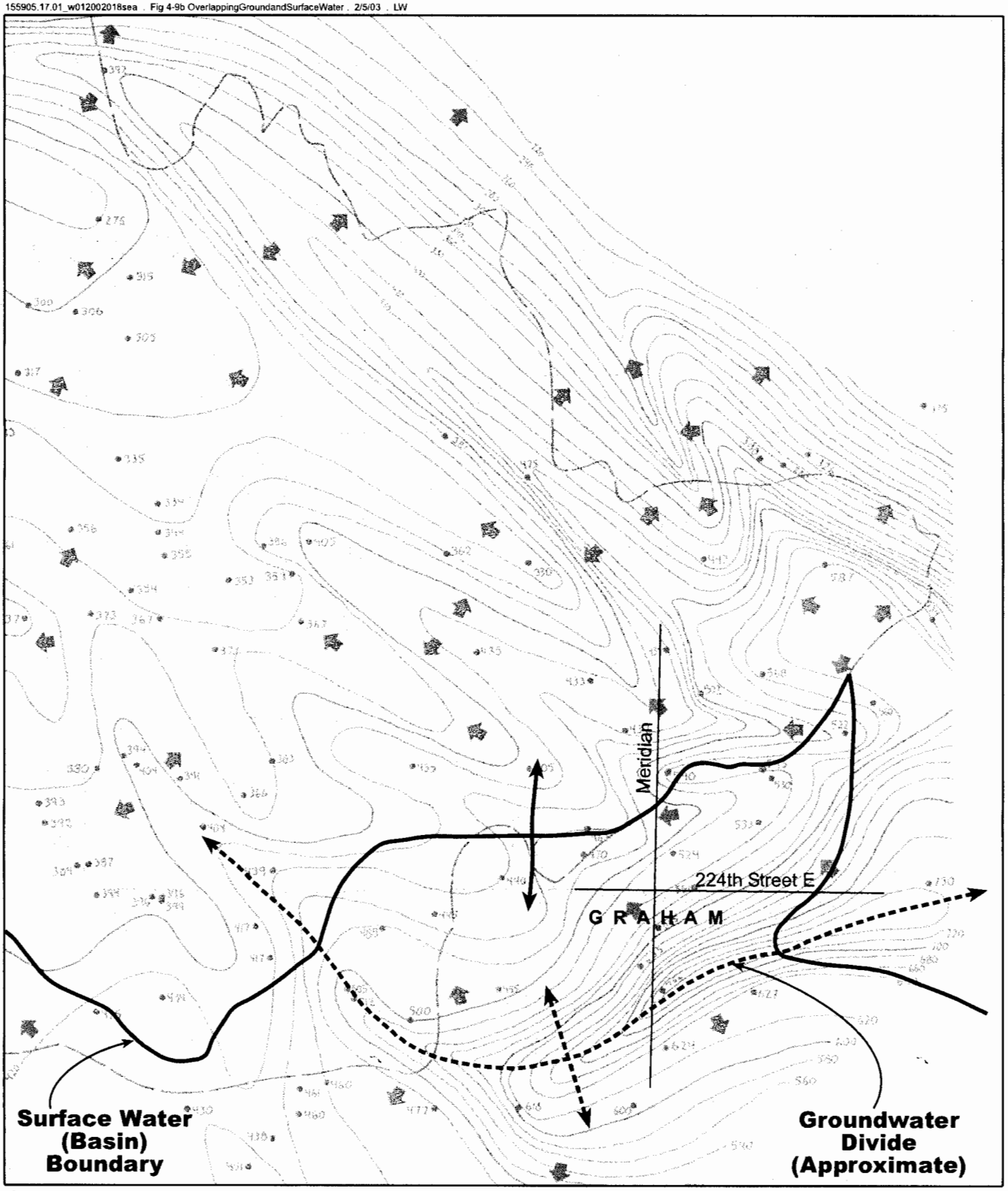


Figure 4-9a
Long Term Well Water Levels
(Source: Sinclair 2001)

Figure 4_9a.xls

155905.17.01_w012002018sea . Fig 4-9b OverlappingGroundandSurfaceWater . 2/5/03 . LW



SOURCE: Brown and Caldwell, 1990

LEGEND

540 — Groundwater Elevation

Monitoring Well

FIGURE 4-9b
Overlapping Ground and Surface Water Divides in the Graham Area

serve 350 residents. The wells feed a 250,000-gallon water tank and a booster pump is planned to improve service. In 1999, the system produced 11.9 million gallons, averaging 32,000 gallons per day. Low pH from one of the wells was the only reported water quality problem with the supply. Aeration is being used to address this problem. There is no sewer system serving the City. This apparently has inhibited larger industry or commercial operations from locating in Roy. The City is considering an option of extending a long interceptor north to the Spanaway sewer service area in order to obtain sewer service from Pierce County.

The Graham Hill Mutual Water Company is located in the northeast portion of the Basin. Information for this water system was obtained from the Water System Plan prepared by SEMCON, Inc. (1998). In 1997, the company supplied a total of 24.5 million gallons to 230 users. This was an average of 66,000 gallons per day. Water is supplied from three wells. The company has two water reservoirs with a total storage of 270,000 gallons. The company serves the northeast portion of the Muck Creek Basin, which is experiencing substantial residential growth. The water system was projected to grow at an 11 percent annual rate through 2010.

The per-capita water use for the two water systems discussed above is about 90 gallons per person per day (gpcd). Most of the customers have relatively small lots (one-half acre, or less) compared to the typical rural lot size in the Basin. The Nisqually River Basin Watershed Assessment, conducted under the state's Watershed Planning Act, RCW 90.82, used an average domestic water use value of 145 gpcd. For purposes of the present study, a figure halfway between these two values (118 gpcd) is used as a reasonable estimate of domestic water use in the Muck Creek Basin. Using the population census and forecast data from Section 5.6, future domestic water use in the Basin can be estimated:

Year	Population	Daily Use (mgd)	Annual Use (acre-ft/yr)
2000	22,883	2.70	3,024
2010	26,326	3.11	3,479
2020	28,088	3.31	3,712
2030	29,089	3.43	3,844

There are no major industrial users of water in the Muck Creek Basin. The Muck Creek Basin has been closed by the State to new applications for surface water permits for several decades.

4.4.7 Agricultural Water Use

The State Department of Agriculture gathers statistics on agriculture at the county level. As a result there are no existing data on agricultural activities or water use specific to Muck Creek Basin. The Pierce County Conservation District reports that there is only limited amount of agricultural irrigation occurring in the southern portion of Pierce County, where Muck Creek Basin is located (Baden 2001, personal communication). The best estimate comes from the 1995 national water use statistics published by the U.S. Geological Survey (Solley 1998). Irrigated crop lands within the entire Nisqually River Basin is reported to be 1,270 acres, with a water use of 2,600 acre-ft/yr. An upper-level estimate for agricultural irrigation of commercial crops in the Muck Creek Basin would be 2,000 acre-ft/yr.

4.5 Water Quality

4.5.1 Long-Term Water Quality Data

Detailed water quality data along Muck Creek and its tributaries are included in "Appendix C." The appendix includes water quality data collected by the Nisqually Tribe taken at stream mile 0.5 (near the Nisqually River) and 6.3 (at Roy) during the period from April 1991 through July 1999. It also includes data collected by Fort Lewis personnel at five stations along Muck Creek and data collected during the period from November 1992 through November 1999. These long-term sample sites are shown on *Figure 4-1*. Neither organization has collected water quality data in the Muck Creek system since 1999.

Muck Creek drains into the lower portion of the Nisqually River, which is classified by the state as a Class A stream under current state Water Quality Standards. Therefore, Muck Creek and its tributaries are also classified as Class A streams by Ecology (WAC 173-201A). State water quality standards are reproduced in "Appendix D." [2] *Table 4-2* shows the number of water quality standards violations measured in Muck Creek. *Table 4-3* shows the average values of water quality data at various locations along Muck Creek for selected parameters. Selected water quality data from these tables are discussed below.

The current (2003) water quality standard for stream temperature is 18 degrees Celsius, set as an upper limit for protection of anadromous fish and resident trout. The mean water temperature of 7.4 degrees Celsius on the South Fork of Muck Creek (*Table 4-4*) appears strikingly lower than the rest of the average temperatures. A review of the data for this site reveals that fewer samples were taken during the summer season at this site, probably accounting for the lower average value. During the warmer months, Nisqually Tribe data indicate that the creek temperature at Roy commonly exceeds the stream standard. The highest summer temperatures in the creek occur at or above Roy. The peak temperature in the data set is 21.5 degrees, upstream of Chambers Lake. This stretch of the creek passes through a series of lakes and large wetlands and is exposed to solar radiation. About 1 mile below Roy, the stream enters a tree-covered ravine and temperatures typically drop by 3-5 degrees Celsius. This phenomenon is further illustrated by same-day temperature data collected in August 1998 and August 1999. On both dates, the stream temperature peaked in or near Roy at 21 and 25 degrees for the respective years. The temperature at the mouth was 7-10 degrees cooler. The principle reason for the cooler stream temperatures is Exeter Spring which introduces cooler groundwater to the stream nears its mouth.

Whiley and Walter (2000) observed a similar trend during a study that monitored stream water temperatures in most of the tributaries of the Nisqually River during the summer of 1998. At their monitoring location near the mouth of Muck, peak temperatures remained at or below 12 degrees, the lowest of any of the tributaries. The majority of the stream flow during this period was from groundwater inflow to the creek and the authors noted that the stream temperature closely reflected that of the regional groundwater.

Upstream, at the eastern edge of Fort Lewis, the temperature on these days was 3-5 degrees cooler than at Roy. No temperature excursions have occurred at the upstream edge of Fort Lewis. The North Fork receives most of its flow from Patterson Springs and from groundwater recharge along its upper reach which is the likely reason for these cooler temperatures.

[2] In 2002, the Washington Department of Ecology proposed major revisions to convert existing state Water Quality Standards to a "use-based" classification system. These changes had not taken place at the time of this Basin Plan.

Only the Nisqually Tribe data contain pH measurements. The station at the mouth meets the pH standard of 6.5-8.5. However, four values at the Roy station fell below the 6.5 standard, the lowest value measuring 6.1.

Table 4-3. Comparison of Water Quality Data to State Standards[1]

Source[2]	River Mile	BEGIN	END	Number of Excursions	Number of Excursions	Number of Excursions	Percent of Excursions
				Temp.	DO	pH	Fecal Coliform
Nisqually Tribe	0.5	4/25/91	7/8/99	0	0	0	0
Nisqually Tribe	6.3	4/25/91	7/8/99	8	4	4	18
Fort Lewis	0.1	11/10/92	11/2/99	0	0	--	0
Fort Lewis	6	12/11/92	11/2/99	0	13	--	0
Fort Lewis	8.5	1/6/93	11/1/99	1	13	--	0
Fort Lewis	MUCKCR04	11/6/92	6/26/97	0	0	--	0
Fort Lewis	14.5	11/6/92	11/2/99	0	0	--	0
Fort Lewis	1.5 [3]	12/9/92	2/17/98	0	0	--	0

[1] State Standards from WAC 173-201A-030

[2] Unpublished water quality data.

[3] South Fork

[4] Percent of samples greater than 200/100 ml

Table 4-4 Average Water Quality Data for Sites Along Muck Creek

Station	Temp °C	pH *	Dissolved Oxygen mg/l	Suspended Solids mg/l	Turbidity NTU	Ammonia mg/l	Nitrate mg/l	Ortho-Phosphate mg/l	Fecal Coliforms** MPN/100 ml
Muck Creek [1,2] at Mouth	10.2	7.6	11.0	5	1.8	0.025	0.060		10
Muck Creek[1] 0.2 mi. below Roy	10.3		6.2			0.035		0.010	9
Muck Creek[2] at Roy	12.9	7.1	9.2	2.4	1.6	0.035	0.042		116
Muck Creek[1] Above Chambers Lake	10.0		6.9			0.030		0.090	5
N. Fork Muck Creek[1] at 8th Ave. E.	10.0		10.6			0.044		0.013	16
S. Fork Muck Creek[1] at 8th Ave. E.	7.4		11.5			0.033		0.014	32

* Median Values
** Geometric Mean

Data Source: 1 – Fort Lewis, unpublished data (11/92 - 11/99), Fort Lewis, Washington
2 – Nisqually Tribe, unpublished data (11/94 - 7/99), Yelm, Washington

Dissolved oxygen levels in the creek appear to be depressed above and below Roy. Two values below 1 mg/l have been recorded and concentrations below the standard of 8 mg/l are common during the warmer months. It is interesting to note that the tribal summer dissolved oxygen data for the Roy station are noticeably higher than the Fort Lewis data upstream and downstream. This may be a result of the relatively rapid flow of the stream through Roy resulting in re-oxygenation of the stream in this area.

Both suspended solids and turbidity data for the two sites in Roy and at the mouth are relatively low.

Ammonia levels appear to be relatively uniform and low along the creek. Nitrate levels are modest but are typically below 1 mg/l. Ortho-phosphorus levels are also modest, rarely attaining 0.5 mg/l. There are no obvious trends in the nutrient data along the creek.

The fecal coliform data have been acquired using two different laboratory analyses. The Fort Lewis data and the data acquired for the present study used the heterotrophic plate count (CFU) method. The Nisqually Tribe data used the standard fermentation technique (MPN), a somewhat less precise technique (American Public Health Association et al., 1998). The data have been aggregated for purposes of this analysis.

The current (2003) state standard for fecal coliforms is expressed as the geometric mean of the samples. The geometric means for fecal coliforms are all below the standard of 100 per 100 ml. A second part of the standard requires that no greater than 10 percent of the samples measure higher than 200/100 ml. As shown in *Table 4-3*, the Roy Station exceeded the state standard in 2 out of 11 samples (18 percent) higher than 200. However, these data were for the period 1991 through 1993, and more current fecal coliform data for this site have not been gathered by the Tribe. The peak value at this site is 4,775. The high count at the mouth of the creek is 875. At the remaining locations, the highest fecal coliform counts are less than 200 per 100 ml.

Neither Muck Creek nor any of its tributaries are on the state's current 303d List of Water Quality Impaired Waters (Beckett 2000, personal communication).

4.5.2 Recent Water Quality Data

Figures 4-10a, b, c show the water temperature data collected at the two flow recording gages discussed earlier. Data gaps occurred during portions of 2001 and most of 2002 due to a combination of factors: damage to the temperature sensor, battery problems and a temporary lack of access to the North Fork gage, located on Fort Lewis, due to security restrictions. Winter temperatures at both sites range from 2-8 degrees C. Temperature builds through the spring, reaching maximums above 20 degrees during the summer. The colder, winter conditions occur starting in November. During the summer, the stream temperature in the main stem at Roy is several degrees higher than in the North Fork. This is likely a result of the very low flows occurring through Roy at this time of the year and to the inflow of groundwater to the North Fork, as discussed in the previous section.

In 2000, there were three short periods in late June and July during which the average stream temperature was above the state standard of 18 degrees, reaching a peak temperature of 21 degrees on June 29. The stream temperature on the North Fork also exceeded the standard, although by a lessor amount.

The diurnal (24-hour) fluctuations occur in stream temperature at both stations. During most of the year, the temperature will typically vary by 1-2 degrees over the day. However during the

summer, the diurnal fluctuations of 3-5 degrees in the streams are common and reach as much as 7 degrees.

During the stream field surveys conducted during the spring and early summer of 2000 and 2001, a limited amount of water quality data were collected. These data are shown in "Appendix C."

Readings for pH generally remain within stream water quality standards. No high levels of turbidity were measured. Turbidity was generally 5 NTUs or less. However several measurements along the middle portion of Lacamas Creek on May 5 ranged from 9 to 15 NTUs, a moderate level and considerably higher than generally seen along Muck Creek. Specific conductance (an indirect measure of dissolved solids in water) remained relatively low.

With one exception, ammonia was quite low, remaining at or below 0.5 mg/l. The total phosphorus and nitrate concentrations were also relatively low and are similar to those in the long-term sample sets of the Nisqually Tribe and Fort Lewis. Total Kjeldahl nitrogen, a measure of ammonia plus organically bound nitrogen, occurred at modest concentrations and did not exceed 1.1mg/l. Total suspended solids were low, reaching a maximum of 8 mg/l. Of the 12 fecal coliform samples taken, 4 (33 percent) exceeded the water quality standard of 100/100ml. The highest value of 610/100ml occurred on July 5, 2001 at the North Fork at 8th Avenue E. However samples collected on two other dates were below the 100/100ml standard.

For the most part, the chemical quality of Muck Creek appears to be in reasonably good shape. Whiley et al. (1994) observed that Muck Creek was the least impacted by nonpoint source pollution of the major streams in the Lower Nisqually River Basin.

4.5.3 LRI Landfill

In the southeastern portion of the Basin (Subbasin MSS1), ongoing water quality monitoring is occurring at the LRI landfill. The landfill has two cells covering 27 acres. When fully developed, it will ultimately cover 168 acres. This landfill opened in December, 1999 and during 2000, the first full year of operation, received 521,000 tons of solids waste (Kleinfelder, 2001). LRI is conducting a long-term monitoring program at the site to ensure compliance with water quality standards. The South Fork of Muck Creek enters the site at 304th Street (SWSC-1), and then flows in a southwesterly direction, leaving the site as it passes under Highway 161(SWSC-2). A small tributary, locally known as the East Tributary (SWET-1) enters the eastern portion of the site, joining the South Fork between 304th Street and Highway 161 (*Figure 4-11*). A network of drainage channels within the active portion of the landfill site conveys surface water runoff to a water quality and detention facility which discharges into a wetland adjacent to the creek.

The two upstream (SWET-1 and SWSC-1) and one downstream (SWSC-2) surface water sites are being monitored weekly for turbidity and suspended solids. These three sites are also sampled quarterly for pH, conductivity, temperature, dissolved oxygen, chloride, nitrate, ammonia, total organic carbon, and fecal coliforms. Finally, each site is sampled annually for a variety of common compounds and volatile organics. In November, 1999, at about the time that the Landfill was opened, relatively high turbidity levels, exceeding water quality standards, occurred in the South Fork following a heavy rain event. This exceedance was thought to be a result of the first flush of the LRI stormwater pond after summer construction (Comstock 2000, personal communication).

Water quality data from the Landfill monitoring through September, 2001 were reviewed. A summary of surface water quality data is shown in *Table 4-5*. The data for the downstream site,

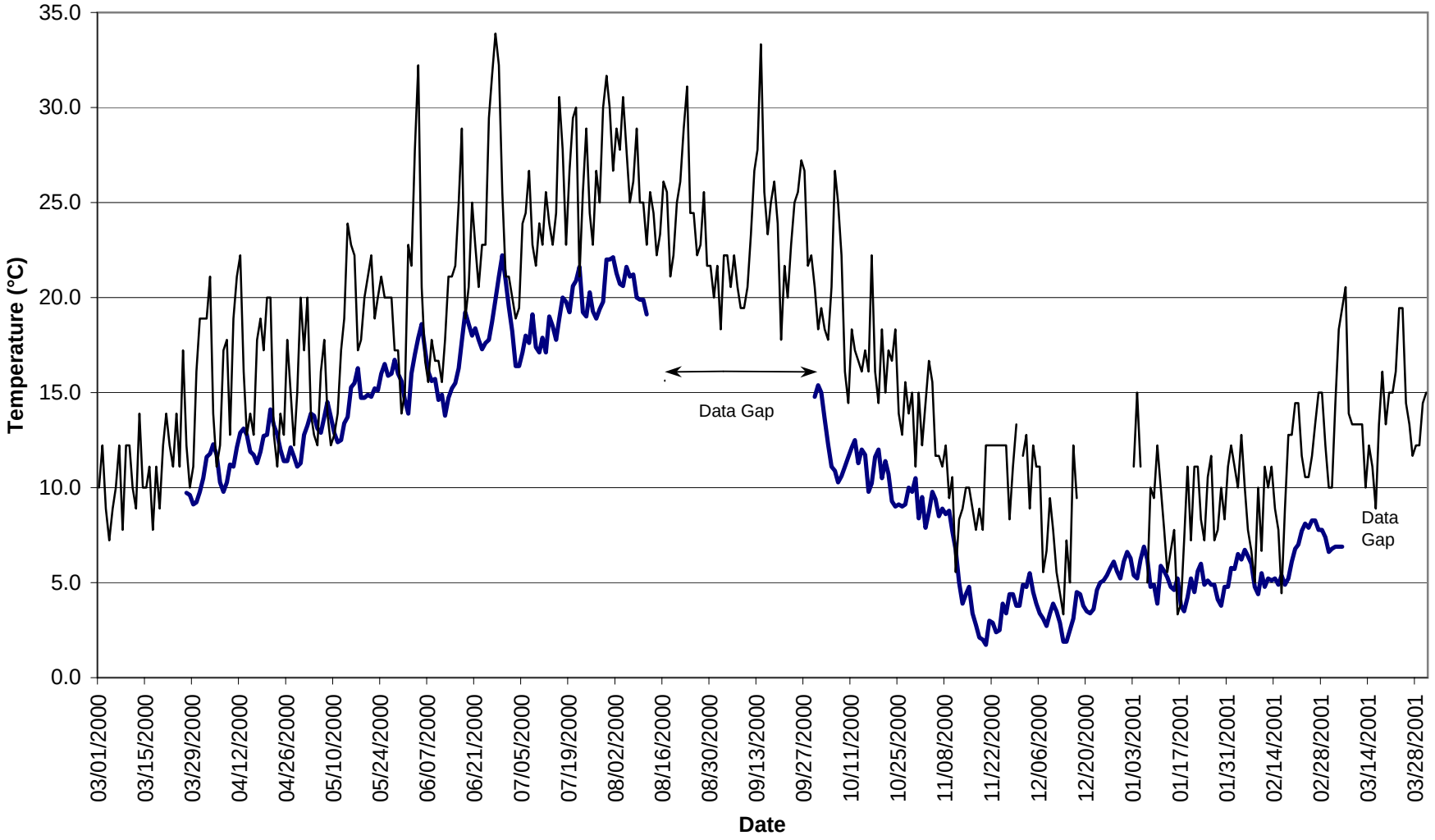


Figure 4-10a
Continous Temperature Data
Muck Creek at Roy
March 2000 to December 2001

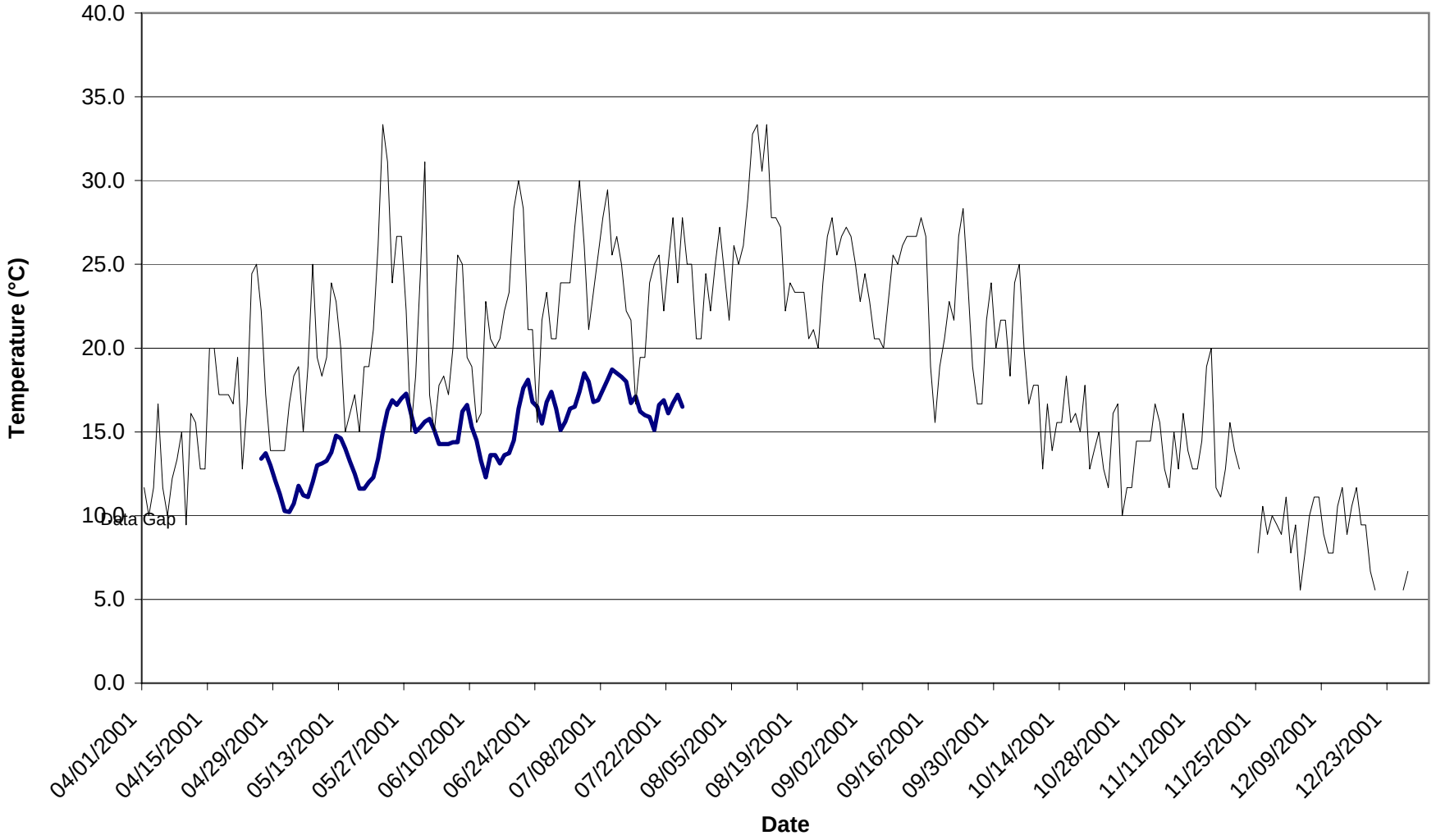


Figure 4-10b
Continous Temperature Data
Muck Creek at Roy
March 2001 to December 2001

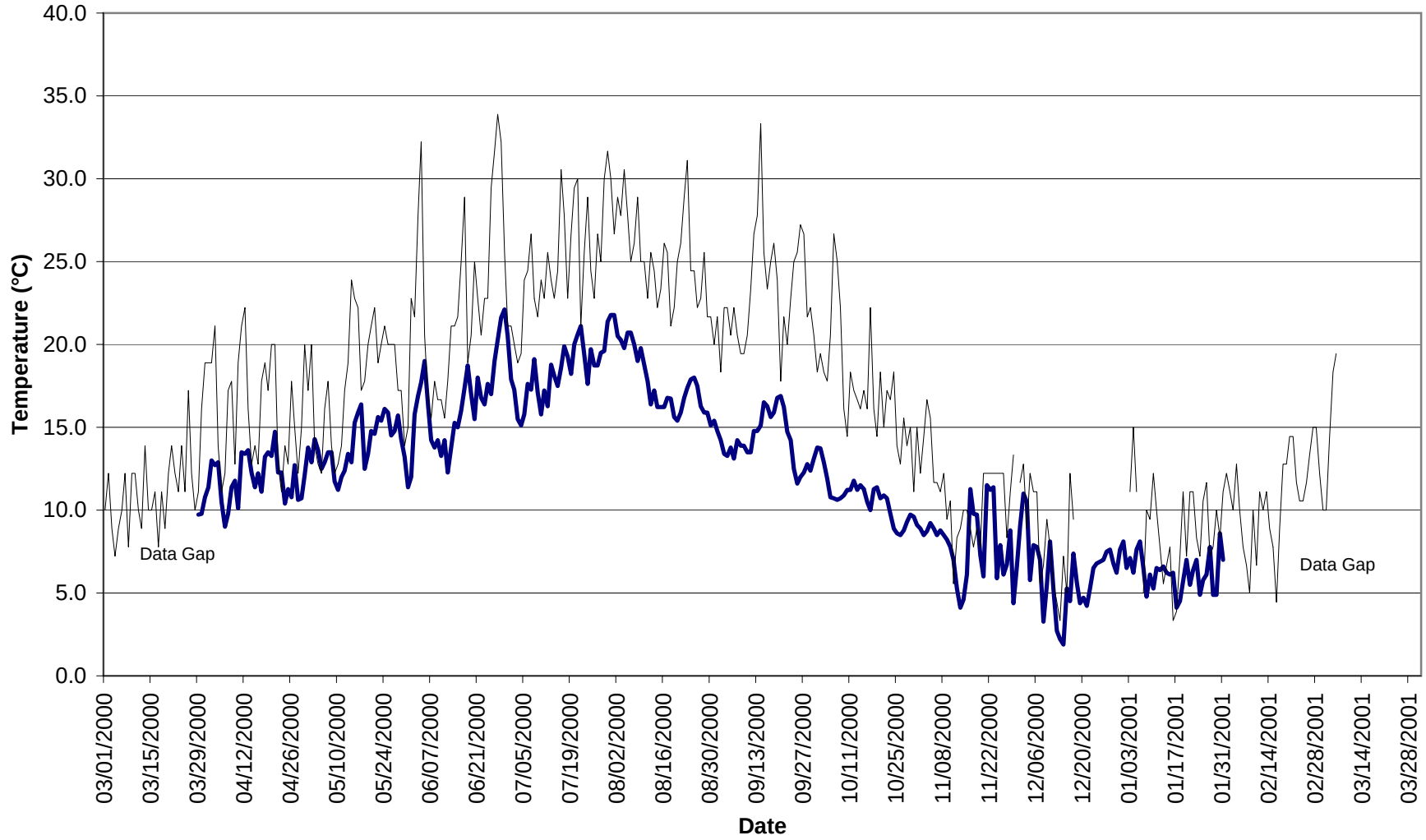


Figure 4-10c
Temperature Data
North Fork Muck Creek at 8th Avenue East
March 2000 to February 2001

which is the South Fork crossing of SR 161, indicate no pattern of elevated turbidity or suspended solids when compared with the upstream site at the 304th Street E crossing.

Turbidity values typically fall in the range of 5-8 NTUs, while suspended solids fall in the range of 5-9 mg/l. These are relatively low values. There were a total of 107 turbidity measurements and 62 suspended solids measurements taken when all three sites had flow. The turbidity readings averaged about 5 NTUs at the both the upstream and downstream sites along the South Fork. There has been no instance where the measured downstream turbidity was more than 5 NTUs higher than the documented upstream turbidity. Suspended solids readings showed no change, averaging 6 mg/l at both sites. The upstream readings on the East Tributary were slightly higher, averaging 8.5 NTUs for turbidity and 14 mg/l for suspended solids.

For the remainder of the water quality parameters in *Table 4-5* there are no significant documented differences between the upstream and the downstream concentrations in the South Fork. The downstream site (SWSC-2) has slightly higher concentrations of dissolved oxygen and total organic carbon. Compared to the two South Fork sites, the East Tributary site (SWET-1) has somewhat lower conductivity and chloride levels. However, suspended solids, turbidity, temperature, total organic carbon and fecal coliform levels are somewhat higher. On at least one occasion at all three sites, fecal coliforms and dissolved oxygen exceeded the water quality standards of 100/100 ml and 8 mg/l, respectively. One temperature standard violation (18 degrees C) occurred on the East Tributary.

Underneath the landfill is a separate leak detection/collection system designed to detect any leaks below the landfill liner. In 2000, about 1.8 million gallons were collected from this system, two-thirds in the first half of the year. Toward the end of the year, several volatile organics were detected in this collected water. None of these substances are commonly associated with landfill leachate and it was concluded that they are associated with migrating landfill gas. A gas collection system has been installed to intercept and burn this gas.

A series of groundwater monitoring wells are sampled quarterly for a suite of water quality parameters and more frequently for water level. This includes two wells located upgradient of the landfill (MW-9 and-10) and five wells which are downgradient of the landfill (MW-1 through -5). The data indicate that groundwater flows northwest beneath the site along a gradient of about 1 percent. The horizontal flow velocity is estimated to be about 45 feet per year (Kleinfelder, 2001). Each location was sampled a total of six times before start of landfill operation in order to develop background data. Upper-level values in each well for this background water quality data have been calculated as the average concentration of each parameter plus three times the standard deviation (*Table 4-6*). The upper-level values are arbitrary calculations, used to identify possible conditions worthy of further review. The water quality of the groundwater in the six sets of quarterly samples taken since the Landfill opened at the end of 1999 was compared with these upper-level values.

MW-4 and MW-1 have, respectively, one and two upper-level exceedances each (*Table 4-6*)**.** MW-2 has five exceedances, with iron accounting for four of them. MW-3 has nine exceedances, with sulfate accounting for five of them. With the exception of iron at MW-2 and sulfate at MW-3, there is no evidence of a pattern of elevated concentrations of any of the monitored parameters in the groundwater downgradient of the landfill.

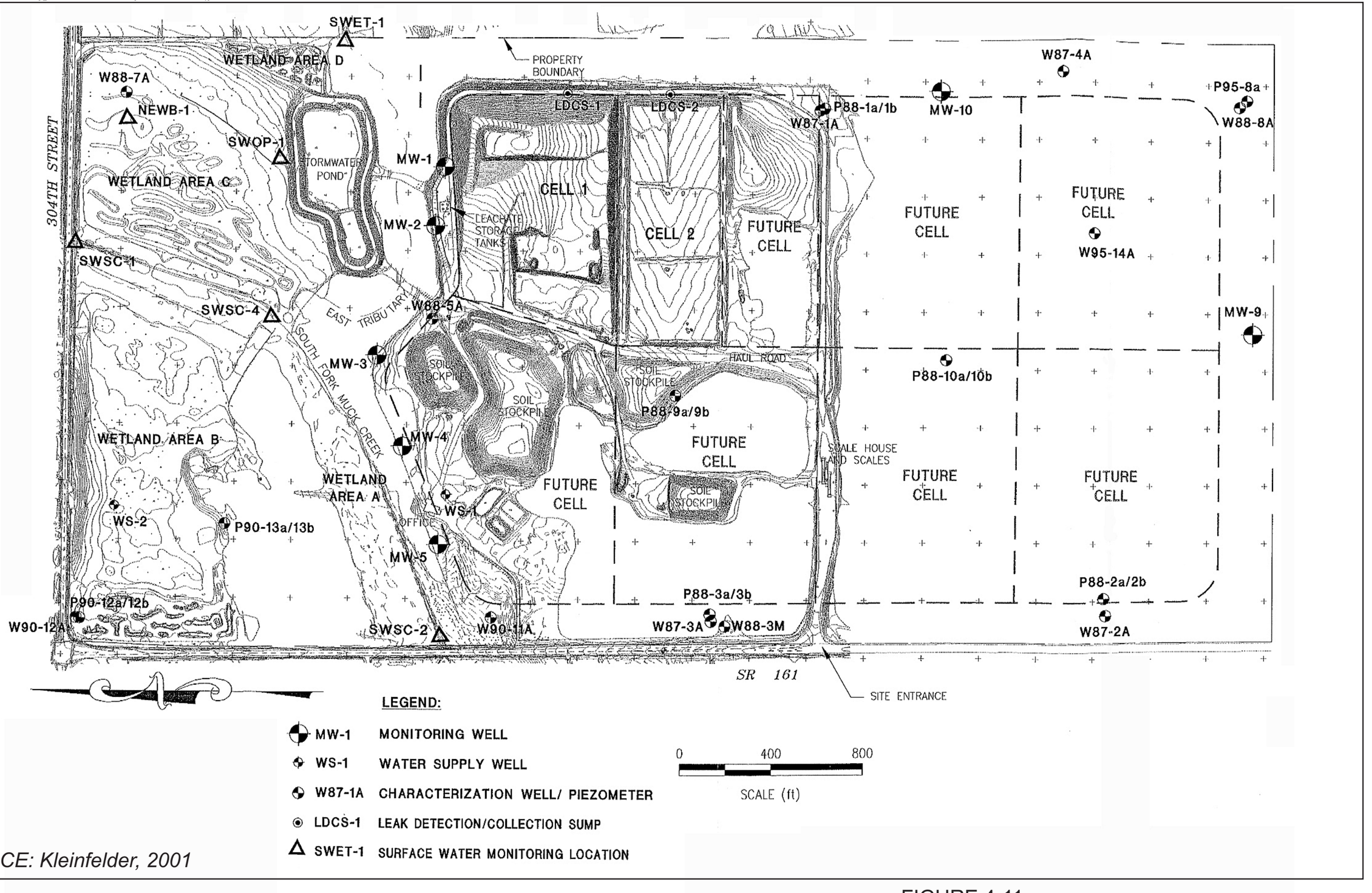
The highest sulfate concentration at MW-3 has been 12.6 mg/l. This is below the average background concentration of 14.8 mg/l measured in 1999 at nearby MW-1. For comparison, the

secondary (taste and aesthetics) drink water criteria for sulfate is 300 mg/l. The highest iron concentration measured at MW-2 has been 0.3 mg/l. The average **background** iron concentration at nearby MW-1 in 1999 was 1.5 mg/l, which is substantially higher. For comparison, the secondary (taste and aesthetics) drinking water criteria for iron is 0.3 mg/l.

Volatile organics have also been monitored on a quarterly basis at the surface and groundwater sites discussed above, with no reported detections. In summary, the monitoring data from the first 18 months of landfill operation show no indication of substantial change in either the surface water of the South Fork, nor the local groundwater. The quarterly monitoring reports are sent to the Department of Ecology and the Tacoma-Pierce County Health Department. The Ecology Hydrologist responsible for reviewing these reports was contacted. He indicated that there was no evidence of downstream problems or noncompliance since the monitoring began (Matthews 2002, personal communication).

Illegal production of a controlled substance, methamphetamine, is a serious problem in many rural areas of Western Washington, including Pierce County. Illegal labs have been discovered in the Muck Creek Basin. The substances used to manufacture this drug could pose potentially serious contamination problems if they were introduced to the surface or groundwater. Depending on the manufacturing process, the following toxic chemicals may be involved with the production of methamphetamine: acetone, anhydrous ammonia, hydrogen chloride, iodine, lithium, sodium metal, sodium hydroxide, sulfuric acid, red phosphorus, and hydriodic acid. After an illegal site is identified, the septic tank is typically test and pumped, if necessary. Materials and soils contaminated with chemicals are removed for proper disposal. However, given the volatile nature of the most prevalent chemicals, the volumes of contaminated materials are usually small (Lavergne 2000, personal communication). No serious water contamination has been reported within the Muck Creek Basin as a result of illegal methamphetamine production.

155905.17.01_w012002018sea . Fig _ LRI Landfill Site and Monitoring Locations . 1/28/02 . jg



SOURCE: Kleinfelder, 2001

FIGURE 4-11

Landfill Site and Monitoring Locations

TABLE 4-5
Summary of Surface Water Quality Data for the LRI Landfill
(January 2000 through September 2001*)

Parameter	Number of Samples	Sample Location** SWET-1	SWSC-1	SWSC-2
Turbidity (mg/l)	107			
Mean		8.5	5.3	5.2
Maximum		136	20	15
Suspended Solids (mg/l)	62			
Mean		14	6	6
Maximum		380	14	9
pH (units)	6			
Mean		6.82	6.85	6.88
Minimum		6.53	6.48	6.62
Conductivity (~S)	6			
Mean		63	75	76
Maximum		92	90	100
Temperature (°C)	6			
Mean		9.9	7.7	7.5
Maximum		24.0	15.9	15.9
Dissolved Oxygen (mg/l)	5			
Mean		8.0	7.6	8.3
Minimum		7.3	6.6	7.3
Chloride (mg/l)	5			
Mean		4.4	5.2	5.2
Maximum		5.6	6.2	6.3
Ammonia-N (mg/l)	5			
Mean		0.08	0.06	0.06
Maximum		0.2	0.11	0.11
Nitrate-N (mg/l)	6			
Mean		0.3	0.6	0.6
Maximum		0.4	1.1	1.1
Total Organic Carbon (mg/l)	6			
Mean		18.5	9.9	10.5
Maximum		26.4	12.0	12.6
Fecal Coliform (#/100ml)	5			
Log Mean		59	39	41
Maximum		>1,600	110	170

*All streams were dry during the September 2001 quarterly sampling. No surface samples taken.
**Refer to Figure 4-11.

TABLE 4-6
LRI Landfill - Inorganic Parameters (mg/L)
Upper Level[1] of Background Groundwater Concentrations

	MW-1	MW-2	MW-3	MW-4	MW-5	MW-9	MW-10
Alkalinity	138 (1)[2]	118	121 (1)	144	142	70	126
Ammonia as Nitrogen	0.34	--	1.20	1.20	0.13	--	--
Chloride	3.1	3.9	2.6 (1)	3.7	4.1	2.5	9.0
Total Dissolved Solids	331	272	199	331	180	209	349
Sulfate	70.3	5.7 (1)	7.0 (5)	8.7	13.4	1.9	15.7
Calcium	21.3	21.4	23.7 (2)	28.3	27.5	11.3	28.2
Iron	8.50	0.13 (4)	--	--	0.14	.--	--
Magnesium	12.5 (1)	11.40	10.60	15.25	13.81	11.54	13.70
Manganese	0.42	0.54	0.25	0.21	0.21	--	0.29
Potassium	3.79	4.34	4.15	4.23	6.55	--	--
Sodium	59.8	21.0	13.6	13.9	14.49	8.05	20.89

[1] Defined as the average of the 1999 (pre-project) background concentrations plus three standard deviations. Calculated from data in Appendices D and G of Kleinfelder (2001).

[2] The numbers in parentheses indicate the number of post-project samples (out of a maximum of six) which exceed the upper-limit value shown.

4.6 Aquatic and Riparian Habitat

Muck Creek is a second-order, lowland Puget Sound stream draining 93 square miles of land with an elevation range from about 140 to 960 feet. Major tributaries include the North Fork, South Fork, and Lacamas Creek. The Basin is fed almost entirely by precipitation in the form of rain and has a considerable groundwater influence. Muck Creek is a tributary to the Nisqually River, entering at RM 10.6 on the north side (right bank). The main stem length is nearly 14 miles and the total length of tributaries is over 50 miles.

The lower 14 miles of the creek flows through Fort Lewis, the lower 2 or 3 miles of which is the steepest section in the Basin. This is the reach where the stream leaves the prairies and cuts through the bluff bordering the main stem Nisqually River floodplain. This reach is characterized by numerous pools and a relatively deep channel. Substrate is correspondingly coarse. Much of the riparian zone within the Fort boundaries is coniferous, with varying habitat quality, ranging from the best buffers in the Basin to impacted and poor habitat. The riparian zone from RM 0 to 4 and 6.5 to 10 is forested and in good condition. The riparian zone from RM 4 to 6.5 and 10 to 14 is limited due to prairie or urban conditions (Salminen, 1997). Above Roy, but still within Fort Lewis, are two important physiographic features. The first is a series of lakes with capacity augmented by low dams. The second is the section of channel that regularly goes dry between August and November.

Muck Creek and its major tributaries transition away from a prairie landscape in the reaches above Fort Lewis. The riparian zone within private lands is typically limited and consists primarily of small patchy second-growth coniferous and hardwood forests interspersed with prairie land consisting of native grasses (Kerwin, 2000).

Muck Creek supports three species of salmonids including chum salmon (*Oncorhynchus keta*), resident and anadromous (steelhead) rainbow trout *(O. mykiss*), and resident and sea-run cutthroat trout (*O. clarki*). Chinook salmon are not known to exist in the Muck Creek drainage area. About one-third of the chum salmon run to the Nisqually River system spawn in Muck Creek. Muck Creek experienced extremely low flow during the fall and winter of 2000/2001. As a result, escapement to Muck Creek was essentially zero. In contrast, the 2001/2002 season produced a record run, with over 20,000 fish returning to Muck Creek (Troutt 2002, personal communication). Most of these fish spawned at Exeter Springs and at the Johnson Marsh spawning channel, both within Fort Lewis. During much of the winter of 2002/2003, flow at the mouth of Muck Creek was insufficient for upstream migration. The situation did not improve until the beginning of February when flows were finally sufficient for fish to enter the creek (Walters 2003, personal communication). This is very late in the season for spawning chum salmon and most of the Muck Creek run probably spawned at other locations in the Nisqually watershed due to lack of access to Muck Creek.

In the late 1970s, the state placed a weir at the mouth of Muck Creek to count spawner escapement. Besides chum salmon, the state counted about 100 steelhead and a few coho salmon. Coho salmon (*O. kisutch)* have not been observed spawning in Muck Creek since the 1980's. However, juveniles have been observed near Johnson Creek on Fort Lewis as recently as 2002, and in the upper reaches of the South Fork in the late 1990's. Current Steelhead numbers are unknown but likely to be lower than the levels counted in the 1970s. Wild steelhead populations have declined substantially throughout Puget Sound over the past 30 years. Although in general, Muck Creek is too low in gradient to be a good steelhead producer, there were considerable numbers of steelhead in the creek up until the early 1990's (Dorner 2003, personal communication). Salmon production above Roy is

severely constrained by the lack of flow in the losing reach just above Highway 507 until mid-December.

No federally protected fish species are present in the Muck Creek drainage, although two protected salmonid species are present in the Nisqually system (i.e., chinook salmon and bull trout). Fish species of concern are shown in *Table 4-7*.

Table 4-7 Fish Species of Concern[1]

Species	Status
Steelhead trout	State monitor species
River Lamprey	Federal species of concern/state candidate and species of concern

1: Includes federal/state endangered, threatened, candidate, and monitor species.

Source: Washington Department of Fish and Wildlife, 1993 – updated via WDFW Sensitive Species web page 2002

4.6.1 Stream Evaluation

The Urban Stream Baseline Evaluation Method (USBEM) in the Tri-County Urban Issues Study (R2 Resources Consultants, 2000) was used to classify salmon habitat quality and quantity for the Muck Creek Basin by reach. The major streams within the Muck Creek Basin were divided into 39 reaches based upon stream slope, geology and tributary inflow locations (refer to *Figure 4-12*). The USBEM methodology allows for the determination of baseline conditions for salmon with particular treatment of urban influences. The analysis is a two-phase process. The initial Phase I is a pre-classification screening, which includes analysis of geomorphic channel constraints, watershed or channel alterations, and known or expected fish distributions. The compilation of this information allows for pre-classification of each channel segment into highly suitable habitat, secondary habitat, and negligible habitat.

Phase I: Pre-Classification Screening

As shown in *Table 4-8*, the Phase I results identified three highly suitable habitat reaches, four negligible habitat reaches, and 32 secondary habitat reaches. The highly suitable and negligible habitat reaches are shown in *Figure 4-12* (the remainder of the reaches being secondary habitat). Phase II of the USBEM includes field review of the reaches that were identified as secondary habitat to further categorize them into good, fair, or poor habitat for the fish species of concern. Phase I identified 45.1 miles or 86 percent of the streams as secondary habitat. During 2000 and 2001, field surveys (verification) were performed on approximately 18 miles of secondary habitat, or about 54 percent of stream length with that designation outside of Fort Lewis (refer to *Figure 4-12*).

In general, channel type did not influence potential habitat suitability in the desktop analysis because the types present are highly suitable for all species of salmonids in the Basin. Cumulative impervious surface was found to be fairly uniform throughout the Basin, ranging from 5 to 13 percent. According to May et al. (1997), adverse impacts resulting impervious

Muck Creek Basin Plan
Pierce County, Washington

LEGEND

- Original Basin Boundary
- Major Roads
- Railroads

Stream Suitability
- Highly Suitable
- Secondary Habitat
- Negligible
- Water Body
- Fort Lewis
- City
- Basin Reach-Original

Basin Reach-Original
- Lacamas
- Main Stem
- North Fork
- South Fork

N W E S

3000 0 3000 Feet

1:72000

PIERCE COUNTY

CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

M30 M25 M20 M15 M35 M40 Mainstem

ML5 ML10

L10 L5 L15 L20 L30 L40 L25 L35

MN5 MN10 MN20 MN25 MN15 MN30

MS5 MS10 MS15 MS20 MS25 MS30 MS35

MSN5 MSN10 MSN15 MSN20

MSS5 MSS10 MSS15 MSS20 MSS25 MSS30

Champers Lake

Muck Lake

Roy

North Fork

South Fork

Lacamas

8TH AVE

24TH AVE

70TH AVE E

MERIDIAN E

224TH ST E

246TH ST

288TH ST

288TH ST E

320TH ST E

340TH ST E

264TH ST E

MOUNTAIN HIGHWAY (SR-7)

KAPOWSIN HWY

TISCH RD S

KINSMAN RD E

CHRISTENSEN

SR 702 S

SR 161 E

EATONVILLE CUT

Figure 4-12
Muck Creek Basin
Reach Delineation
(5/01)

surface area can become evident at a coverage level of 6-8 percent. Channel and flow modification ranged widely in different subbasins and did result in differences in habitat suitability scoring. However, the channel modification statistics in *Table 4-8* are likely to be low estimates due to the fact that they were based, on observable channelization using aerial photos. The numbers used for riparian breaks were high throughout most of the Basin. The high numbers were strongly influenced by highly fragmented and narrow riparian zones in most areas upstream of the lower main stem reaches. Potential habitat suitability differences between reaches were also strongly influenced by known salmonid utilization distribution. In general this factor is largely controlled by stream size as well as gradient.

The only stream reaches rated as "highly suitable" during the desktop analysis were found in the lower mainstem of Muck Creek. The primary reason for this was the very wide riparian buffer width in these reaches. The North Fork reaches all fell into the "secondary" habitat category because of the high number of riparian breaks. The same is true for the South Fork (also called South Creek). Reaches designated as "negligible" habitat were either classified that way due to their location above the uppermost extent of utilization by anadromous salmonids or due to a complete lack of riparian vegetation.

Phase II: Field Observations

The Urban Baseline Evaluation Method (USBEM) Phase II included a field evaluation of stream reaches and a quantitative assessment of habitat characteristics of a portion of the sites determined in Phase I. A total of 18 of the stream reaches were evaluated in the field during the spring and early summer of 2000 and 2001. The channel types identified in the desktop analysis were confirmed in the field as predominantly Palustrine and floodplain types. Palustrine channels are highly to moderately suitable for salmonids. Palustrine channels are commonly flooded wetlands, beaver complexes, side channel backwaters and sloughs. Mostly they provide high quality wetland function and velocity refugia during high flow conditions. Floodplain channel types are highly suitable for all salmonid species. This channel type typically has a moderate to high degree of meandering and is highly responsive to LWD in terms of creating pools and other complex habitat features.

Phase II parameters include riparian condition, substrate composition, embeddedness, bank condition, benthic invertebrate community characteristics, passage barriers, pool frequency, channel pattern/bedform, large woody debris, and water temperature. In addition to field habitat assessment, local residents were interviewed for information on fish use, habitat alteration, land use, water flow fluctuation, and any other factor that might influence habitat condition. Field notes are included in "Appendix E." The results from the USBEM analysis are used in the process of selecting the appropriate recovery options for the species of concern.

Muck Creek and its tributaries are relatively low gradient in all but a few short headwater reaches and the lower 3 miles. The abundant gravel supply from the underlying geological formation produces abundant riffles where gradients exceed 1 percent slope. Because of the low gradient, glides and long shallow pools were common. Riffle areas were found to be sparse, mostly due to the shallow gradient. Boulder-formed microhabitats and large woody debris (LWD) formed pools are rare. In general, quality pools are rare and thus serve to limit fish production. Because of the abundant large gravel and small cobble substrate, macrobenthic invertebrate production appears to be high with mayfly and caddis hatches observed in late April and early May.

One of the reaches was determined to have a higher habitat suitability rating than was assigned under Phase 1. The perennially-flowing section of the lower South Fork (MS15-above 8th Avenue E), originally classified as Secondary, was found to have Highly Suitable habitat (*Table 4-8*). Three other reaches were down-graded from Secondary to Negligible habitat, due largely to extensive channel damage from livestock access. These included reaches L30, L35 and MS20.

From the stream observations in the field, it would appear that spawning habitat, while marginal in quality, is not limiting for coho and chum salmon. There is enough spawning habitat to match rearing habitat abundance for these species. Spawning habitat does appear to be a limiting factor for cutthroat trout due to the scarcity of suitable gravel size. Substrate throughout the Basin was found to be either large gravel, cobble, or sand/silt. Cutthroat trout prefer small gravel. Small gravel in homogeneous deposits, and also in areas of adequate depth and velocity, were rare. Cutthroat redds were found in early May wherever these rare combinations of suitable substrate, depth, and velocity conditions were met.

Fine sediment was found to be a moderate problem in most areas and a major problem in a few areas. Despite the low velocity water observed in most locations examined, gravel and cobble substrates were found to be embedded 25 to 50 percent for the most part. While this level only constitutes fair spawning and macroinvertebrate habitat conditions (according to the assessment methodology used in this study) it represented expected habitat conditions in the stream, considering the low gradient and apparently large silt loading. There were some stream sections with deep silt deposits, however. These areas were associated with cattle ranches. Specifically, these areas existed where long pools were located just below cattle grazing. Deep deposits of silt were found next to streambanks that were stabilized by reed canary grass. Dammed pools and beaver complexes were rare but where they existed, heavy silt deposits were found over large areas.

See *Table 4-8*, Stream Reach Screening.

Unstable banks were not found to be common due to the heavy vegetative cover on streambanks and a general lack of channel meandering. Where bank failures were found, they were associated with intense livestock use.

There are numerous reaches of main stem and tributary streams with no riparian growth other than grasses. With the exception of the prairie reaches within Fort Lewis, treeless reaches are almost exclusively associated with cattle ranching, hay fields, or horse pastures, although not necessarily cleared for that purpose. Many (perhaps most) areas now grazed or farmed were once prairie lands. Riparian vegetation is dominated by alders, maples, cascara, Oregon ash, cottonwood, salmonberry, blackberries, and reed canary grass. Reaches in Fort Lewis are dominated by mixed mature conifer growth, except for the prairie stretch between RM 9-14. Outside of Fort Lewis, riparian corridors are generally quite narrow due to development. Buffer zones can be as narrow as one row of trees or completely absent, limited by cattle and horse grazing. Even where fence-line setbacks preserve riparian vegetation, the buffer widths are not more than 40 or 50 feet. In addition, riparian growth is generally composed of young trees (less than 30 years). This explains, in part, why there is minimal LWD. Unfortunately, it also means that LWD recruitment potential will be low for years to come. Even then, LWD naturally recruiting to the streams will be mostly hardwood species, which are less desirable than conifer species.

Many reaches along Muck Creek have been invaded by reed canary grass, which limits habitat for salmon by encroaching into the channel as well as growing in it. Generally throughout the Basin, where the stream has no riparian tree canopy and is open to the sunlight, reed canary grass can be found. Reed canary grass, once established, prevents willow, alder, and other riparian trees from becoming established. This, in turn, eliminates the potential for LWD recruitment. Riparian tree cover provides better shade and food (terrestrial insect) production than reed canary grass. Tree root masses are important for creating undercut bank habitat when a meandering channel pattern creates lateral scour. At the low stream gradients which typically occur, reed canary grass seems to hold the bank so well that it discourages lateral channel migration and, as a result, meander formation. It also cleaves together rather than becoming undercut when exposed to lateral scour. There are areas where reed canary grass is so thick in the channel that adult salmon passage may be impossible. These areas will need to be restored to ensure a properly functioning habitat. The Pierce County Conservation District, the Stream Team, Muck Creek Council and the Natural Resource Conservation Service (NRCS) have programs in place to work with farmers on pasture management and fish habitat restoration, including riparian planting and fencing. In addition, the Nisqually Tribe and Fort Lewis identified and performed numerous riparian planting projects to enhance salmonid habitat. Many such projects were seen during the field survey. The projects included removal and/or control of reed canary grass prior to planting various native species of plants and trees (Salminen, 1997). A list of recent projects is included in "Appendix F."

There is widespread evidence of past channelization and channel confinement. Part of this evidence comes from the relatively young age of the riparian trees compared with adjacent upland trees. In general, there are few trees close to the stream which are older than 30 or 40 years. Some of this may be due to large scale land clearing (whole lot) with only the riparian trees allowed to grow back. There are low levees bordering the streams at numerous locations with flat terrain. Many of these are barely discernable. In other locations they are quite obvious. Besides the obvious lack of meandering that channelization typically creates, the channel does not appear to have enough cross-sectional capacity. The floodplain is so narrow that there are almost no gravel bars, despite the abundant supply of gravel in the channel.

The combination of channel confinement, low gradient, and flat topography leads to a condition of local flood risk. It is highly likely that residents removed LWD decades ago in an effort to facilitate water conveyance out of the Basin. LWD removal and lack of replacement due to narrow riparian corridors of relatively young trees has resulted in a condition where there are few high quality ponds. In recent years, channel constriction has been exacerbated by invasive reed canary grass. This has led to dredging efforts in some areas. In addition, cattle grazing has eliminated riparian growth in some areas and has contributed significant silt loading. All of these factors contribute to elevated late summer stream temperatures, which is commonly an important limiting factor in lowland streams. The cattle and horse ranches have the potential to contribute nutrient loading to Muck Creek, in addition to silt. Abundant growth of attached algae and emergent macrophytes found in some of the stream reaches are evidence of nutrient input. However, water quality data for the streams indicate that phosphorus and nitrogen levels are not significant at the present time.

Aquatic insect (macroinvertebrate) production and community structure is also a good indicator of water quality conditions, although this parameter is also affected by sedimentation and bedload movement. Triplicate macroinvertebrate samples were taken at four to six sites in the stream system *Figure 4-13*), both in the late summer of 2000 and

again in the late summer of 2001. The species in each sample were identified and scored according to the Benthic Index of Biological Integrity (B-IBI). There were three sites that provided samples in both years. The two scores for each of these sites were reasonably similar for both years (*Table 4-9*). The B-IBI sores ranged from 22 to 30 in 2000 and from 18 to 28 in 2001. Based on these criteria, most of the sampling locations indicated "poor" habitat conditions using this methodology.

Table 4-9 B-IBI Scores at Various Stream Locations

Sampling Station Locations**	**2000 Scores**	**2001 Scores**
Muck Creek mainstem at Roy (near RR trestle)	22	*
North Fork Muck Creek on Harlow Ranch	20	18
North Fork Muck Creek at 70th Ave. E	24	26
Lacamas Creek above Hwy 507	30	*
Lacamas Creek below Hwy 507		28
Lacamas Creek at 56th Ave. S.	24	20
Lacamas Creek at 24th Ave. S.	26	*

*This site was either dry or formed a stagnant pool and was therefore not appropriate for B-IBI sampling.
**Sample locations are shown on Figure 4-13.
Note: B-IBI score ratings (according to USBEM) are as follows:
Good: 32 and greater
Fair: 31-25
Poor: 24 or less

4.6.2 Critical Water Features

Several springs along Muck Creek provide substantial inflows of water to the creek. These include Exeter Springs at RM 2.5; Nixon Springs located above Chambers Lake at RM 9; Johnson Springs, also in the same area; and Patterson Springs, which forms the headwaters of the North Fork (*Figure 4-1*). The first three springs lie within the Fort Lewis Military Base; however, Patterson Springs lies within land owned by the City of Tacoma. It is important for the long-term ecology of the stream to preserve all of these springs. Similarly, a large system of wetlands exists, much of it along or adjacent to the streams (refer to *Figure 4-1*). These wetlands play a key role in the natural treatment of stormwater inflows, attenuating peak flows, and providing base flow to the streams. Their protection will be an important factor in the long-term development of the Muck Creek Basin.

Muck Creek Basin Plan
Pierce County, Washington

LEGEND

- Original Basin Boundary
- Major Roads
- Railroads
- B-IBI Sample Locations
  - 2000
  - 2001
- Stream Survey Reaches
- Stream
- Water Body
- Township and Range
- Sections
- Ft. Lewis
- City

N
W E
S

3000 0 3000 Feet

1:72000

PIERCE COUNTY

CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

Figure 4-13
Muck Creek Basin
Stream Survey and B-IBI Sites

4.7 Upland Habitats

4.7.1 Upland Flora

The Muck Creek Basin, which includes Lacamas Creek, supports several vegetation communities: conifer, deciduous, and mixed conifer–deciduous forests; grasslands (prairie); and wetland habitats. These plant communities can be grouped into four habitat types: conifer forests, oak/mixed oak woodlands, prairies, and riparian/wetland zones. This section will not discuss riparian/wetland zones, which are analyzed in Section 3.6, *Aquatic and Riparian Habitat*. The upland habitat descriptions are as follows.

Conifer Forests: Three semi-distinct forest types are contained within the Basin: Thuja plicata (western red cedar), Pseudotsuga menziesii (Douglar fir), and Pinus ponderosa (ponderosa pine).

Western red cedar type occupies the moist soil regimes within the Basin, with hemlock (*Tsuga* species) scattered within this habitat type. The upper watershed, particularly the South Fork, is the area where it usually dominates. Cedar typically abuts the Douglas fir ecotone, and in some instances the prairie habitats, as one moves to the central portion of the Basin. Understory vegetation varies with ninebark (*Physocarpus capitatus)* and berry (*Vaccinium* species) varieties as common associates. This forest type has experienced large-scale logging activity in the past century, which has reduced the amount of mature historic forests in the Basin.

Douglas fir dominates most of the conifer habitats in the Basin at this time. This forest type grows in the variety of habitat conditions (soil moisture, topography) between the cedar and prairie ecotones. Hemlock stands/mosaics are scattered throughout this forest as well. The understory is dominated by salal, serviceberry, and red-osier dogwood, with sapling growth of red alder in open pockets. The forest edge contains young Douglas fir, red alder, hawthorn, blackberry, and vine maple as the predominant vegetation species. Douglas fir dominance within the Basin has increased with the absence of burning practices once employed by Native Americans to maintain the prairie habitats. This encroachment has reduced the amount of the unique prairie ecotones within the Basin.

Scattered ponderosa pine forest types are present in ridge lines dissecting the valley, and sometimes occupy pure stands accompanying the dry soil conditions associated with prairie habitats. Bunchgrasses and Oregon grape are typical species inhabiting the understory layer of this forest type. Ponderosa pine primarily occurs within the borders of the Fort Lewis Military Base. These stands are unique as they are the only native stands of ponderosa pine in Western Washington.

The Basin's historical conifer forests, to a larger extent, have been lost to agricultural and residential land uses.

Oak/Mixed Oak Woodlands: Oak woodlands range from communities of pure Oregon white oak to a mix of oak, conifer, and deciduous trees. Pure oak stands are found on the prairie/grassland/agricultural edges, and are perceived as transition zones between prairie and conifer forest ecotones. Understories in these habitats are various grass species, with fescue and bluegrasses in high densities. Other deciduous or mixed conifer/deciduous forests consist of Douglas fir, big leaf maple, black cottonwood, western red cedar, hemlock, Oregon ash, and red alder. Understory species vary from prairie grasses to various shrub species.

Prairies: Traditional prairie ecotones exist in the Basin in limited quantities. Land development, primarily agricultural forms such as dairies and pasture uses for livestock, have modified the traditional prairie vegetation species to high quantities of plants that tolerate grazing. Native prairie habitat vegetation is dominated by bunchgrass, mainly Idaho fescue. Forbs and herb plants that have intermixed to prairie habitat are balsam root, camas, and Nuttall's violet.

Disturbances (Agriculture) and fire suppression have significantly modified the species composition in the Basin. With these changes in land use, invasive plants, most notably Scot's broom and bentgrass, have established themselves throughout the Basin. The Scot's broom, in particular, has become quite common in the prairie area within Fort Lewis.

The lower portions of the North and South forks and 3.6 miles of the main stem of Muck Creek flow through a large prairie. Most of this prairie lies within the eastern portion of Fort Lewis and is called the 13th Division Prairie. Over the past century, this prairie has been considerably reduced in area due to encroachment of the surrounding forests. To better quantify this phenomenon, two sets of aerial photography covering the northern portion of the Basin were obtained from the National Resources Conservation Service (NRCS). The two sets of photographs were from flights conducted in 1955 and again in 1990.

The prairie limits were defined by the tree lines where the forest met the prairie. Areas with approximately 10 percent trees or less were also included in the prairie delineation. Clusters or islands of trees within the prairie extents were excluded from the prairie area total.

The open prairie surrounding area from each set of aerial photography was digitized as a GIS layer which can be seen in *Figure 4-14*. The acreage of each was then electronically calculated. The prairie area in 1955 was on the order of 5,480 acres. By 1990 the areal coverage had declined to 4,200 acres. This represents a reduction in prairie area of 23 percent over a 35-year period, or an average loss of 37 acres per year. From general reports for the area, prairie lands had already significantly declined in areal extent prior to the 1950s. Intensive forest management, including forest fire protection programs, is likely the major reason for the decline in prairie lands in the Basin.

The Muck Creek Basin contains white-top aster (*Aster curtus*), as Washington sensitive species and federal candidate species. Three other state sensitive species that occur within the Basin are: 1) bristly sedge, 2) green-fruited sedge, and 3) small-flowered trillium.

4.7.2 Upland Fauna

The Muck Creek Basin contains a mosaic of wildlife habitat. The variety of habitat types results from the marine influence of Puget Sound, the glacial plains (soils) and associated vegetation, and various hydrologic and topographic features in the Basin.

The U.S. Army identified 53 mammal species, 164 bird species, 9 reptile species, and 11 amphibian species that occur or potentially occur at the Fort Lewis military installation. Because wildlife generally span habitat types, the fences surrounding Fort Lewis do not limit wildlife movement or occurrence in the Basin.

Mammals: The conifer, oak/mixed oak, and deciduous forests provide habitat for black bear, cougar, blacktail deer, elk, raccoon, coyote, and a variety of bats and rodent species.

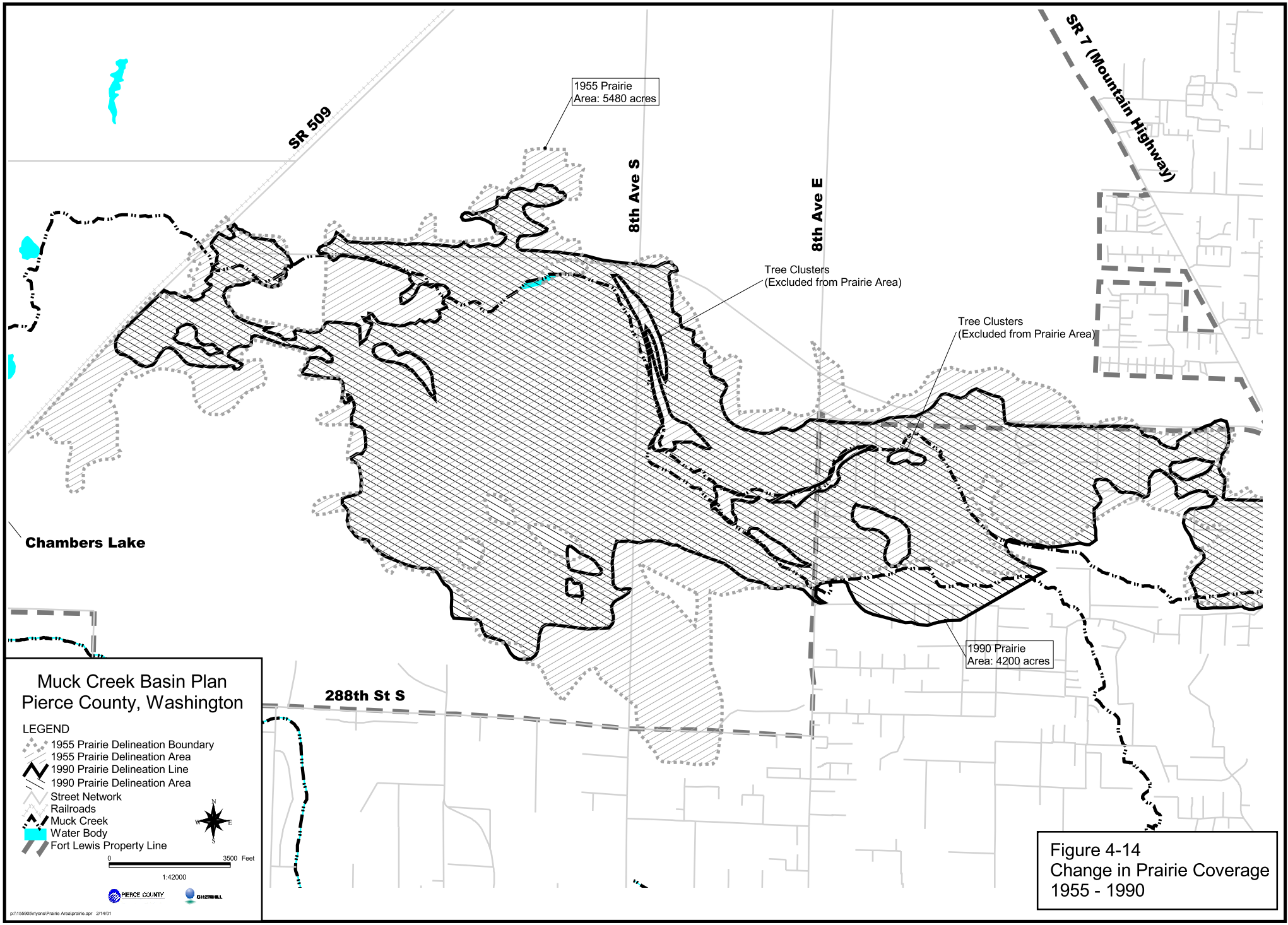


Figure 4-14
Change in Prairie Coverage
1955 - 1990

Prairie habitats provide food and cover for small- to medium-sized mammals such as mice, shrew, voles, and cottontail rabbits.

Birds: Bird species are vast and diverse; therefore, this listing will provide only the partial species list of the most common birds noticeable in the Basin. The various forest communities support eagles, hawks, owls, jays, woodpeckers, and various resident and migrant passerine and warbler species**.** Oak woodlands offer critical habitat for band-tail pigeons and great-horned owls.

Prairie macroenvironments contain habitat suitable for a wide range of birds from raptors of several species (redtail, northern harrier, etc.) to the American robin to the migrant violet-green swallow. Waterfowl, primarily geese and ducks, inhabit prairie communities as foraging grounds. Of particular interest is the recovering western bluebird population, a state designate Monitor Species, within the Basin. A nesting box program has helped provide adequate nesting habitat for this species, which depends greatly upon open grasslands (prairies) to forage.

Reptiles and Amphibians: Conifer forests can support regional reptile species such as western toads, northwestern salamanders, and the common garter snake. Amphibians such as the bullfrog, newt, and salamander are typically found in wetlands and along riparian corridors.

Species of Concern: Three mammals, nine birds, one reptile, and two amphibians were identified as occurring or potentially occurring at or near Fort Lewis (1984, 1992, and 1993). See *Table 4-10* for Species of Concern that may inhabit the Muck Creek Basin.

Table 4-10 Upland Species of Concern[1]

Species	Status
Bald eagle *(Haliaeetus leucocephalus)*	Federal/state threatened
Northern spotted owl *(Strix occidentalis)*	Federal threatened–State endangered
Marbled murrelet *(Brachyramphus marmoratus)*	Federal/state threatened
Mardon Skipper Butterfly *(Polites mardon)*	Federal/state candidate
Northern goshawk *(Accipiter gentilis)*	State candidate
Northwestern pond turtle *(Clemmys marmorata)*	State endangered
Puget Blue Butterfly *(Plebejus icaiodes blackmorei)*	State candidate
Townsend's big-eared bat *(Coryhorhinus townsendii)*	Federal/state candidate
Spotted frog *(Rana pretiosa)*	Federal candidate–State endangered
Streaked Horned Lark *(Eremophila alpestris)*	Federal candidate–State endangered
Roy Prairie pocket gopher *(Thomomys mazama)*	Federal/state candidate
Common loon *(Gavia immer)*	State candidate
Pileated woodpecker *(Dryocopus pileatus)*	State candidate
Purple martin *(Progne subis)*	State candidate
Taylor's (Whulge) Checkerspot (*Euphydras editha taylori)*	Federal/state candidate
Valley Silverspot *(Speyeria zerene bremnerii)*	Federal species of concern/state candidate
Vaux's swift *(Chaetura vauxi)*	State candidate
Western toad *(Bufo boreas)*	Candidate
Western gray squirrel *(Sciurus griseus)*	State endangered

1: Includes federal/state endangered, threatened, candidate, and monitor species.

Source: Washington Department of Fish and Wildlife, 1993 – update via WDFW Sensitive Species web page 2000; USFWS 1993.

CHAPTER FIVE

Identification of Problems

5.1 Problem Definitions

A number of general problems have been identified within the Muck Creek Basin. One problem, unusual for most streams within the Puget Sound Basin, is the intermittent nature of the stream resulting from the loss of all flow during portions of many years. Other problems typical of many developing basins include flooding, water quality problems, habitat degradation, and land use/natural resource conflicts. These are discussed in the following sections.

5.2 Intermittent Flow

The intermittent nature of Muck Creek limits salmon production to existing runs whose spawning and early life cycle are compatible with the fluctuating flow patterns of the creek.
Flows become intermittent at some point during most summers. Numerous stream reaches experience zero flow at some point in time each year (refer to Section 4.4). The two lowest reaches experiencing intermittent flows (and thus most important in terms of fish passage) are the reach through Roy and the reach above and below Highway 507. The reach at Highway 507 typically goes dry up to two and a half miles upstream (or about one mile downstream from 8th Avenue South; see Figures 4-6 and 4-7). In addition, most of the lower South Fork goes dry at some point during the year. During an unusually dry year, such as 2000-2001, the flow may even cease at the mouth of Muck Creek.

Some local residents attribute the bulk of the stream flow losses to activities at Fort Lewis. They have expressed an opinion that past military maneuvers stream crossings by tanks and other military vehicles disturbed the stream bottom and broke a natural "seal“, causing the stream to percolate into the underlying gravels. In recent years all stream fords within Fort Lewis have been hardened with a concrete section to prevent further disturbance of the stream bed (Clouse 2000, personal communication).

A scientifically plausible explanation for the stream flow losses is related to the permeable geologic deposits through which long lengths of the stream flow, particularly the Steilacoom Gravel. The recently completed study performed by the Department of Ecology (Sinclair, 2001) documents significant seepage of flows through the stream bottom both on and off of Fort Lewis. Measurements made during that study document that the stream losses through the stream channel occur when the groundwater table falls below the elevation for the stream bottom. Sections of the stream will gain flow when the water table is above the stream bottom during the wet season and lose flow when the water table is below the stream bottom during the dry season (refer to Section 4.4).

Another cause of flow variation in Muck Creek in the Roy area is water level regulation of two lakes, Chambers and Johnson. These lakes are located on Fort Lewis, several miles upstream of Roy (Figure 4-1). Flow monitoring at Roy during the past two years has shown a sharp reduction in flow in the late spring. On June 20-22, 2000, the flow declined suddenly from 10 to 4 cfs**.** From June 5-8, 2001, the flow again dropped from around 50 cfs to less than 1 cfs.

Discussion with Fort Lewis indicates that the outlet to Chambers Lake was adjusted during these two periods to retain water in the lake. It is reported that dequate flow was maintained downstream of the lake to allow for trout passage into the lake, although no flow measurements were made (Zuchowski 2002, personal communication).

Given the close interaction between the shallow groundwater and streamflow, there is concern that increasing development in the Basin may reduce the groundwater and thereby contribute to stream desiccation. Development in the Basin may also negatively alter the flow regime of the streams. Replacement of forest cover with impervious areas results in more rapid runoff of rainfall, reducing the opportunity for infiltration and slow release from the groundwater. The reduction of wetland areas reduces their flow contribution to the streams. Both of these can have the effect of reducing base flows in the streams during the summer dry season, accentuating intermittent flow conditions. These issues are further discussed in Chapter 7.

5.3 Flooding

Figure 5-1 shows the floodplains as mapped by the Flood Insurance Program and administered by the Federal Emergency Management Agency. The mapping for the North Fork and Lacamas Creek is being updated by Pierce County using more refined topographic data (Northwest Hydraulic Consultants, 2002).

Other sources of flood information included County maintenance staff, County drainage complaint files and input from local citizens both in the field and at public meetings. The great majority of flood and drainage problems in the Basin involve ponding which occurs in local topographic depressions. In addition some undersized culverts can result in road flooding. As documented in Section 4.2, the Muck Creek Basin is generally rural in nature. Flooding tends to be highly localized, affecting one or two residences, and there are no major widespread flood problems in the Basin. Flood and drainage problems are summarized in “Appendix G.” Several undersized culverts under existing roads exhibit fairly regular flooding over the road. These include 288th Street E-South Fork and Southeast Fork crossings and 252nd Street E-North Fork crossing.

An analysis of culverts within the Muck Creek Basin was performed in 1991 (Montgomery Engineers, 1991). Twenty-nine culverts were analyzed. Sixteen of the twenty-nine culverts did not meet the design criteria, which was to safely pass the 25-year design flow with a water depth less than 1.5 times the diameter of the culvert. Five of these culverts were designated as high priority projects and have been studied in additional detail for this report. Three additional culverts were added to this study, based upon field observations. Specific flood and drainage problems are further discussed in Chapter 6.

The City of Roy has had several instances of flooding in the mid-1990s (Jacobs 2000, personal communication). A blocked culvert forced Lacamas Creek out of its banks, upstream of Highway 507. Ponding water in Muck Creek flooded property near the City Park. The latter situation has been largely remedied by a channel clearing to remove the large quantities of reed canary grass that had accumulated. A similar effort by the City of Roy cleared Muck Creek upstream to Muck Lake.

Overall, invasive species growth within various tributaries is also aggravating flood hazards in the Basin. As discussed in Chapter 4, Reed Canary Grass reduces stream flows and causes backup and localized flooding in various locales within the Basin.

Muck Creek Basin Plan
Pierce County, Washington

LEGEND

- Original Basin Boundary
- Major Roads
- Railroads
- Stream
- Water Body
- Township and Range
- Sections
- Fort Lewis
- City

Floodplain

- 100 Year
- 500 Year

N W E S

Note: Based on 1995 FEMA Information

3000 0 3000 Feet

1:72000

PIERCE COUNTY

CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

3/00

T18N

R2E

R3E

R4E

Muck Creek

Chambers Lake

Muck Lake

Roy

Lacamas

N Fork Muck Cr

S Fork Muck

8TH AVE

24TH AVE

8TH AVE S

70TH AVE E

MERIDIAN E

MOUNTAIN HWY E (SR 7)

224TH ST E

246TH ST

264TH S

288TH ST

288TH ST E

298TH ST

KAPOWSIN HWY

320TH ST E

340TH ST E

336TH ST S

SR 702 S

TISCH RD S

KINSMAN RD E

CHRISTENSEN

SR 161 E

EATONVILLE CUTOFF

HART'S LAKE LOOP RD S

Figure 5-1
Muck Creek Basin
Floodplain Map
(3/00)

5.4 Water Quality Degradation

There are two major water quality issues occurring in the Muck Creek Basin: temperature, and bacteria. The water quality standards for these two parameters are frequently exceeded. Toxicants such as heavy metals and organic chemicals have not been identified as a problem in the Basin and are not expected to pose water quality problems because of the lack of major industry and low density urban development.

High water temperature in the late summer is a common limiting factor in lowland Puget Sound streams. Removal of riparian vegetation in combination with naturally low stream flows may lead to temperatures that are stressful to salmonids, especially coho salmon (chinook salmon are less temperature-tolerant but are not present in Muck Creek). The young chum salmon hatched in the creek out migrate in the spring and therefore are not around during the periods of higher stream temperature in the summer. Riparian buffers are commonly completely absent along the streambanks, exposing the stream to the full heating effects of the sun. The temperature standard is commonly exceeded along the middle portion of the creek and its tributaries. The highest recorded temperatures (in excess of 20 degrees Celsius) occur in the vicinity of Roy. A detailed description of temperature data is included in Section 4.6, *Water Quality*.

The primary source of the bacteria problems appears to be from livestock. Cattle ranching operations are scattered throughout the Basin but seem to be concentrated somewhat in the Lacamas drainage. There are numerous locations where cattle are allowed free access to the stream channel. In such cases, stream side vegetation is diminished or absent, streambanks are collapsed and fecal materials may enter the stream directly. Local runoff can flush this material into adjacent streams. The highest concentrations of pollutants often occur from rain events which occur at the end of the dry season, when stream base flow is typically at its lowest level of the year, providing minimal dilution. The result of this contamination is elevated bacteria counts. Elevated bacteria counts are usually not a problem for fish, but are a problem for livestock and humans.

Nitrate, ammonia, and phosphorus are classified together as nutrients because they all stimulate plant growth. Although the available water quality data indicate only moderate levels of these nutrients in the creek, there is ample evidence of nutrient enrichment in the Muck Creek Basin. Coarse streambed materials such as cobbles were found to be moderately to heavily covered with filamentous algae as early as April. The B-IBI data indicates a moderate to strong nutrient effect. High numbers of beetles, oligochaetes, chironomids and snails all point to nutrient enrichment. Low numbers of intolerant taxa, high species dominance, and generally low species diversity all point to some type of habitat impairment, although some of this effect could be from sedimentation. The relatively low diversity and abundance of mayfly, stonefly and caddis indicates a moderate effect. However, they are present in sufficient numbers to indicate that pesticides are not a problem in the Basin.

5.5 Habitat Limiting Factors

In Chapter 4, limiting factors were presented, along with a description of the existing conditions observed during field surveys. Many of the factors that limit salmon production are the same factors that have been degraded due to development and other human activity. This section, is

organized into the following categories: riparian function, fish passage, sedimentation, channel morphology, and exotic plant species.

Riparian Function

Fine sediment problems are usually associated with bank instability. Bank instability can be caused by riparian vegetation loss or excessive flow rates. While both of these factors are at play in the Muck Creek Basin, it is likely that the former is more of a source of degradation than the latter, although sedimentation appears to be less of a problem than some of the other factors. During field surveys, the only unstable banks observed were those affected by cattle grazing. In some areas where cattle were heavily grazed and had free access to the creek, sedimentation problems were extreme, at least in the first, low-gradient section of stream following the impacted streambanks.

Loss of tree canopy cover over the creek channel affected habitat by reducing or removing shade, overhead cover, terrestrial insects, large woody debris (LWD), and leaf litter recruitment. Reduction of shade raises water temperatures and shifts the community structure of macroinvertebrate insect production by greatly increasing algae production, while reducing the detrital-based food chain. Overhead cover is important to salmonids simply in terms of protection from piscivorous birds. Fish will avoid open areas when the areas are fully exposed, even when they provide suitable habitat. LWD is important in pool formation, instream cover, substrate for insect production, gravel transport, and complex habitat formation. Complex habitat is important for providing a range of microhabitat conditions for the different life stage requirements of different species of salmonids. For instance, a submerged log might scour a pool, provide cover, and form a suitable spawning area immediately downstream.

In general, riparian community impacts throughout the Muck Creek Basin are typical of farming/ranching areas of lowland Puget Sound. The early settlers cleared the land as best they could. The various riparian areas, being the best for grazing because of their close proximity to water, were also cleared. Prairie areas tended to have less forested area to clear and were a natural first choice for ranching. Many of the riparian areas cleared in the past have been allowed to reestablish in a narrow band, sometimes as narrow as a single row of trees wide. Other areas have fenced setbacks of 30 or 40 feet. While this may be adequate for shading and energy sources, it is not adequate for LWD recruitment, according to National Marine Fisheries Service guidelines. In addition, very few conifers are present in these riparian zones, except within Fort Lewis. The federal guidelines for riparian zone widths are based on LWD recruitment potential to streams. On smaller fish-bearing streams, the minimum width desired is 150 feet (one generic conifer tree height). The minimum riparian buffer width for streams of any size has been set at 50 feet for forest management purposes. Some new residential properties in the Basin have cleared of riparian vegetation and lawns have been planted to the water's edge, but this does not appear to be a common practice. A number of riparian planting projects were seen while conducting field surveys. Projects that were more than a year old were observed to be generally successful, at least for the willow cuttings. Cedar and other conifer plantings were much less successful. These plantings were frequently observed to have died.

Fish Passage

The intermittent nature of Muck Creek has had a significant impact on fish passage and salmon population for some time. Long-time residents claim that the main stem was perennial at all times in the distant past. The 1950s and 1960s occurred during a wet period of the decadal precipitation cycle. Williams et al. (1975) states: "The major limiting factor to salmon production

in Muck Creek is intermittent flow. The timing of all salmon runs is regulated by the flow regime. Muck Creek is accessible only after the middle of December, and flows generally begin their decline in late spring and continue throughout the summer and fall months." This observation made over 25 years ago is a fairly accurate representation of those made in recent years. The distinction to be made is that the East Fort Lewis reach started to go dry in mid-May in the spring of 2000. During the drought period of 2000-2001 the upper portion of the main stem of Muck Creek dried up in early May, 2000. Except for one or two very brief periods, this stretch of stream did not flow again until late 2001, staying dry for nearly a year and a half. The lower end of Muck Creek, near its mouth with the Nisqually River, was dry through much of the winter of 2000-2001, completely blocking fish migration into the Muck Creek system (Troutt 2002, personal communication).

Salmonoid runs in Muck Creek occur relatively late compared to most in the Puget Sound region. This suggests that the intermittent nature of the creek has existed for a long time; long enough to shape the timing of the runs. This condition, which appears to be worsening (Clouse 2000, personal communication), limits salmon production by constricting spawn timing, incubation, and early-rearing opportunities. Reed canary grass has also formed a physical barrier to fish passage in some stretches of the creek.

Sedimentation

Sedimentation appears to be caused primarily by unrestricted livestock access to streams, rather than excessive peak flows. There was very little evidence of side or down cutting observed during stream surveys. Although it is likely that some of the sediment load is caused by suburban development, none was observed. Sedimentation was found to be locally heavy in very low gradient areas such as in glides, but was only moderate in areas of intermediate gradient. Unfortunately, glides make up a considerable portion of the total habitat in the stream system above Fort Lewis. Riffle areas with gradients of 0.5 to 1.0 percent, in general, had gravel/cobble embeddedness from 25 to 50 percent. However, many areas were found with embeddedness of 25 percent and less. While this is far from optimal, it is potentially useable for fish spawning. This lack of suitable stream substrate is likely to lower egg survival rates from ideal conditions but is probably not the most important factor limiting salmon production in the system, at least given the low salmon population numbers in the upper basin (see the *Fish Passage* section, above). At low densities, fish have more opportunity for redd site selection and will pick out the least embedded riffle areas for spawning. In addition, chum salmon, the dominant salmon in the Watershed, are more tolerant of fine sediment in redds than some of the other species. Interestingly, reed canary grass growing on the channel edge appears to filter and retain suspended sediments, based on the expanses of soft but vertical streambanks stabilized solely by this invasive grass.

Channel Morphology

Much of Muck Creek and its tributaries have been channelized at some point in time. Most of this probably occurred a long time ago, when the Basin was first settled. To the early residents, the Muck Creek watershed posed a problem for farming and ranching. The relatively flat terrain and size of the streams lent themselves to beaver activity, which almost certainly exacerbated the slow draining nature of the Basin. Low-lying lands were probably flooded much of the time, limiting hay production. This was partially solved through a program of channel clearing and beaver eradication. LWD removal from the channels to prevent local flooding problems still occurs in the Basin. Unfortunately these activities impact salmon, but really do little for solving flood problems. The basic problem with flood control practices within the Basin appears to be the width of the floodplain. The stream has been confined to relatively and artificially narrow

channels. In flat terrain, a stream with the flows carried by Muck Creek, should have a floodplain that is perhaps 100-feet wide in the main stem, 50-feet wide in the North Fork, South Fork, and 30-feet in Lacamas Creek. The present-day floodplains are closer to 50-feet, 22-feet, and 15-feet, respectively. The combination of channel constriction, straightening, and clearing increases water velocity and significantly degrades habitat quality for salmon. Quality pools are now rare. Pools that do exist are shallow and lack in-water cover. During the field survey of the South Fork, the reach from RM 2.3 upstream to RM 5 appeared to be close to the presumed natural channel morphology. At RM 2.3, the wider floodplain and presence of very large maples produced a series of very deep corner pools with associated gravel point bars, alternating with riffles, which is excellent habitat for salmon. Unfortunately this reach goes dry in the summer. Around RM 3.3, the South Fork becomes perennial. This reach also has old growth trees including 60+year old cedars. This reach has some of the best pools seen within the entire upper Muck Creek Basin during the stream surveys. Again, the channel is wider at 30-40 feet, even though the channel is confined between ravine slopes.

Problem Plant Species

Reed canary grass is a significant problem in the Muck Creek Basin. The plant is widespread and works to fill small channels and confine the larger channels. This leads to reduced channel conveyance capacity and flooding hazard. Reed canary grass removal is accomplished by dredging out the channel. Such activity tends to have great detrimental effects on the channel. Suspended sediments deposit downstream, degrading habitat there. After a few years, the reed canary grass returns. The solution is to shade the reed canary grass out of the riparian zone with trees. Revegetation projects being carried out by Fort Lewis and the County Conservation District are accomplishing this along portions of the creek, but the scope of this effort needs to be greatly expanded.

5.6 Future Population, Land Use, and Natural Resource Conflicts

Future Population

Future population within the Muck Creek Basin was determined by using the Puget Sound Regional Council (PSRC) long-range population forecasts for Forecast Analysis Zones (FAZs) within Pierce County. The forecast was done for the years 2010, 2020 and 2030. Although the PSRC forecasts were last updated in May of 2001, the forecasts do not include the results of the 2000 Census. During 2002, the PSRC plans to release revised population forecasts.

For purposes of this study, future population estimates for each FAZ were calculated in direct proportion to the area of the Basin lying within each FAZ. The implicit assumption in this approach is that the population is uniformly distributed within each FAZ. The results are plotted on Figure 5-2. Plotted on this figure is the Basin population estimated from the 2000 Census (23,435 in Section 4-2). The census tracts used in the 2000 Census are smaller and more numerous than the FAZs used by PSRC. The 2000 Census data is also considerably more updated. Therefore, this single point represents the best-estimate of actual population within Muck Creek Basin. This point is about 18 percent higher than the area-proportioned population curve. This probably reflects the uncertainty of the PSRC forecast and the assumption of uniform population distribution within the FAZs. It was assumed that the growth-trend shown in

the figure (i.e., the slope of the line) was correct. The initial forecast was therefore increased by 18% to yield a best-estimate of future population growth within Muck Creek Basin.

Year	Muck Basin	Pierce County
• 1998:	22,883	--
• 2010:	26,326	813,000
• 2020:	28,088	892,000
• 2030:	29,087	952,000

According to the forecasts, the population within Muck Creek Basin will increase approximately 12 percent between 2000 and 2010. However, the growth rate will slow down considerably between 2010 and 2020, constituting only a 7 percent increase in population between these years. According to the PSRC forecast, population growth within the Basin will continue to slow down between 2020 and 2030, with only a 4 percent increase predicted in population growth. Both these rates are lower than for Pierce County as a whole. A map and a listing of the FAZs within the Muck Creek Basin is shown in "Appendix I."
Pierce County maintains a detailed land parcel database. This database contains the location and the type of use of each existing land parcel within the County. Using residential parcels, this database was used to develop an independent population estimate specific to the Muck Creek Basin.

Using County-wide statistics, each single-family residential parcel was assigned a population of 3.5 while each multi-family and mobile home parcel was assigned a population of 2.7 persons per unit.

Parcels listed as Vacant were assigned a prospective occupancy of 3.1, the average of single-family and multi-family/mobile home occupancy rates. Ultimate population within the Basin was calculated by adding the population associated with existing vacant parcels. The results are summarized as follows:

Existing:	23,430
Ultimate*:	30,204

*Existing plus vacant parcel-associated population

It is interesting that these two values closely match, respectively, the 2000 Census population and the 2030 population estimate (shown above) for the Basin.

Future Land Use

The northeastern portion of the Muck Creek Basin has experienced relatively rapid development, as are many other rural areas throughout Pierce County and the Puget Sound region. Recent development pressures from the State Highway 7 and 161 corridors have been extending into the Basin. This is particularly true of the Graham area, which lies on the southern fringe of the rapidly growing Puyallup and South Hill area.

In recent years Pierce County has established zoning in the Basin that is in accordance with the Growth Management Act (GMA) guidelines for Urban and Rural development areas. The existing zoning designations throughout the Basin were created by the County's Comprehensive Plan, which was written to implement the GMA's goals of preserving rural lands from increasing urban development. As shown in Figure 5-3, most of the Basin is currently zoned for agricultural or rural residential development. The southern and eastern portions of the Basin are mostly designated as Rural 10 or Agricultural lands (1 housing unit per 10 acres), which together comprise over 60 percent of the Basin. Rural 5 (1 housing unit per 5 acres) is another dominant category, covering 11 percent of the Basin. Commercial zoning remains quite low, comprising less than 1 percent of the Basin. The northeastern portion of the Basin is zoned

Rural 5 (1 housing unit per 5 acres), with a large, designated Rural Activity Center in the vicinity of Meridian and 224th Street East. The headwaters of the North Fork of Muck Creek are in this part of the Basin.

Zoning statistics for the Muck Creek Basin are summarized in Table 5-1.

Figure 5-2. Population Forecast for the Muck Creek Basin

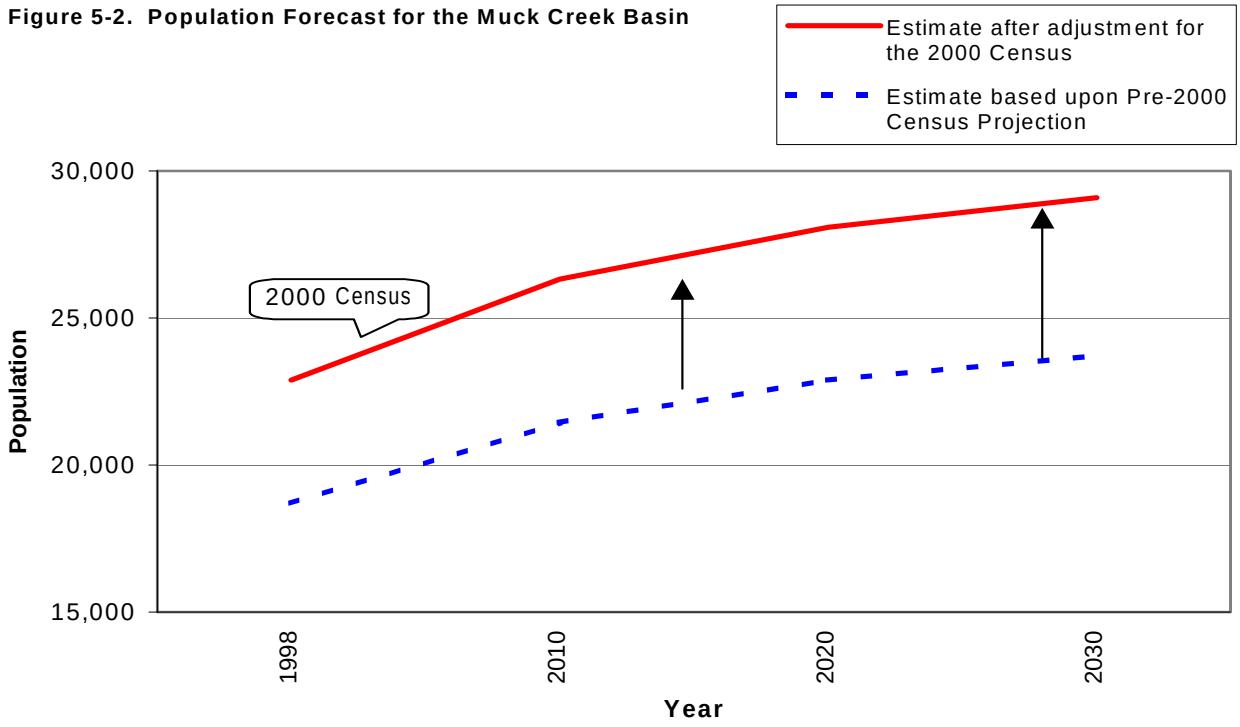


Table 5-1 Future Land Use Patterns (Zoning)

Zoning Category	Acres	Percentage of Basin[1]	Percent Impervious Surface
Agricultural	5,536	9.3	5%
Moderate Density Single Family (Roy)	213	0.4	40%
Reserve Ten	367	0.6	5%
Roy	162	0.3	40%
Rural Activity Center	419	0.7	55%
Rural Five	6,641	11.2	5%
Rural Neighborhood Center	77	0.1	35%
Rural Ten	31,258	52.6	6%
Fort Lewis	14,867	25.0	5%

1 Does not add to 100 percent due to rounding.

Muck Creek Basin Plan
Pierce County, Washington

T18N

R2E

R3E

R4E

Muck Creek

N Fork Muck Cr

S Fork Muck

Chambers Lake

Muck Lake

Lacamas

8TH AVE

24TH AVE

8TH AVE S

70TH AVE E

MERIDIAN E

MOUNTAIN HWY E (SR-7)

224TH ST E

246TH ST

264TH S

288TH ST

288TH ST E

298TH ST

KAPOWSIN HWY

320TH ST E

340TH ST E

336TH ST S

TISCH RD S

KINSMAN RD E

CHRISTENSEN

SR 161 E

SR 702 S

EATONVILLE CUT

HART'S

LEGEND

- Original Basin Boundary
- Major Roads
- Railroads
- Stream
- Water Body
- Township and Range
- Sections
- Ft. Lewis

Future Zoning-Original

- Agricutural
- Roy
- Reserve Ten
- Roy
- Rural Activity Center
- Rural Five
- Rural Neighborhood Center
- Rural Ten

N W E S

3000 0 3000 Feet

1:72000

PIERCE COUNTY

CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

Figure 5-3
Future Land Use
(6/01)

Note: The green area immediately south of Roy has since been incorporated into the City of Roy.

Land Use/Natural Resource Conflicts

Most of the creek runs through lands that are zoned at low densities. Therefore, future build-out of the Basin will be at relatively low-densities and can be configured to minimize major direct impacts associated with urban development to the creek system. However, clearing of forest for low-density rural development and agricultural uses could alter the creek's natural flows and habitat conditions. Continuing residential and commercial development in this area, even at the designated densities, could impact the creek by increasing the amount of impervious surfaces that contribute high runoff to the creek. New buildings, roads, and other impervious surfaces would increase stormwater flows and nonpoint pollution to the creek.

One area that is particularly vulnerable to impacts from development is the area around Patterson Springs. This spring is the headwaters of the North Fork of Muck Creek and the source of its perennial flow. Development in its vicinity could reduce flows in the North Fork due either to additional groundwater withdrawals, reducing spring flows, or due to possible removal of the extensive wetlands downstream of the springs.

Future development within the Muck Creek Basin will result in additional impervious area. This impervious area could increase runoff and impact the stream system. Future impervious area in the Basin was estimated in a manner similar to that used to estimate existing impervious area (see Section 4.2). To derive the future estimates of impervious area, the Zoning designations in the County Comprehensive Plan were used as an indicator of future land uses (Figure 5-3). The impervious area percentages for each zoning category were obtained from information provided by Pierce County Water Programs and are shown in Table 5-1. The calculated, future impervious area percentages are shown, by subbasin, in "Appendix J." Future Impervious area coverage is shown in Table 5-2. In most cases, the future impervious area coverage calculates to about one percent less than that calculated from the existing Land Use coverage (Section 4.2). This is because the Zoning is a generalized designation for the area and does not necessarily reflect pockets of higher-density development. This is particularly evident in the Graham area in the northeast portion of the Basin. The Zoning for this area indicates one dwelling per five acres (impervious area of 6 percent). However, there is substantial existing development at densities of one to two homes per acre in this area (impervious area of 12-20 percent). This is reflected in the existing Land Use map for the area (Figure 4-3).

Table 5.2 Percent Impervious Area Coverage by Tributary Area

Tributary	Based upon Zoning[1]	Based upon Land Use[2]	Future[3]
Lacamas	5.7	6.3	6.4
Main Stem – Muck	5.6	6.3	6.3
North Fork – Muck	7.3	10.2	10.8
South Fork - Muck	6.0	6.8	7.3

1. Calculated from Basin Zoning
2. Calculated from Basin Land Use
3. Land Use-based plus known County development applications (from Table 5-3)

Because of this, the land use-based impervious area percentages are used as the basis for the future-conditions impervious area percentages (Table 5-2). In effect, development within most of the Basin will maintain the rural, low-density land uses and is not expected to substantially increase the amount of impervious cover currently seen in most of the sub-basins. An effort is underway to develop a land use plan for the Graham community. This community includes much of the eastern portion of the Muck Creek Basin. This plan could lead to changes in zoning designations in this area and possibly some areas of higher-intensity development. Measures for assuring adequate control of stormwater runoff are discussed in Section 10.2.

A database search using the Pierce County Planning and Land Services (PALS) on-line permitting web-page was initiated in order to identify active applications for preliminary and final plats within the Muck Creek Basin. The database was searched for new applications and for extensions of existing applications for the period: 2000 through early 2002. The search identified eleven preliminary and final plat applications within the Basin (Figure 5-4). There are also plans to build an elementary school and a junior high school.

Table 5-3 summarizes this development information. The eleven plats propose a total of 572 lots on 366 acres, for an average residential density of 1.6 dwelling units per acre. In addition, two schools covering 20 acres are proposed. The total amount of new impervious area associated with this development is 87 acres. Over 70 percent of this new impervious area would occur in the Graham area (North Fork Subbasin). In addition to the development listed in Table 5-3, the LRI Landfill is a significant development not shown on the Land Use map (Figure 4-3). The active portion of this landfill will eventually expand in size to cover 168 acres. Although this site will not be completely impervious after site stabilization, the site will be graded to promote surface runoff, rather than infiltration. An equivalent impervious factor of 70 percent is assumed, yielding an equivalent impervious area of 118 acres. The future, tributary area impervious percentages shown in Table 5-2 have been adjusted to reflect the additional development specifically reviewed in this paragraph.

The South Fork area shows a 0.5 percent increase in impervious area, increasing from 6.8 to 7.3 percent. Nearly all of this is attributable to the LRI Landfill, which is currently in operation. In the case of LRI, a stormwater detention pond operates to control peak runoff to the South Fork. The Lacamas and Main Stem areas show very little change in impervious area. The North Fork area could undergo a 0.6 percent increase in impervious area coverage. At 10.8 percent impervious cover, this portion of the Muck Creek Basin is the most highly developed. A large Rural Activity Center has been designated the vicinity of Meridian and 224th Street East, in the upper portion of the North Fork tributary area. This type of development will result in concentrated land use densities with associated high levels of impervious surfaces. The upper portion of the North Fork tributary area has a limited drainage system, since much of the runoff in this portion of the Basin ponds in natural low spots and infiltrates into the ground. There is a high potential in this area for shallow flooding problems to occur as development increases. Higher density development will need to emphasize onsite retention and/or the utilization of regional infiltration ponds.

Virtually all of the domestic water used in the Basin comes from groundwater. There are no sewer systems in the Basin and most domestic water is returned to the groundwater via septic drainfields.

TABLE 5-3 Applications for Development in the Muck Creek Basin*

# (see Figure 5-4)	Parcel #	AREA (acres)	Subdivided Lots	Lots/acre	Percent IA**	IA (acres)	Subbasin
1	0418093030	5.0	8	1.6	20	1.0	MN30
2	0318243040	10.0	20	2.0	25	2.5	MN10
3	7637000011	15.0	4	0.3	6	0.9	MN10
4	0417074011	19.0	12	0.6	10	1.9	MS20
5	0418171011 0418173000 0418174018 0418174008 0418171012	223.5	402	1.8	25	55.9	MN30
6	0418331049	9.5	34	3.6	40	3.8	MSN20
7	0317061017	18.0	18	1.0	15	2.7	L10
8	0317061018	32.0	32	1.0	15	4.8	L10
9	0418114009	3.8	4	1.0	15	0.6	MN30
10	0418118003	7.5	15	2.0	25	1.9	MN30
11	0418164025	23.0	23	1.0	15	3.5	MN30
Subtotal		366.3	572	1.6		79.4	
21	0418273005	9.5	Elem. School	N/A	25	2.4	MSN20
22	0318251005	20.0	Middle School	N/A	25	5.0	MN20
TOTAL		395.8				86.8	

* January, 2001

** Impervious Area

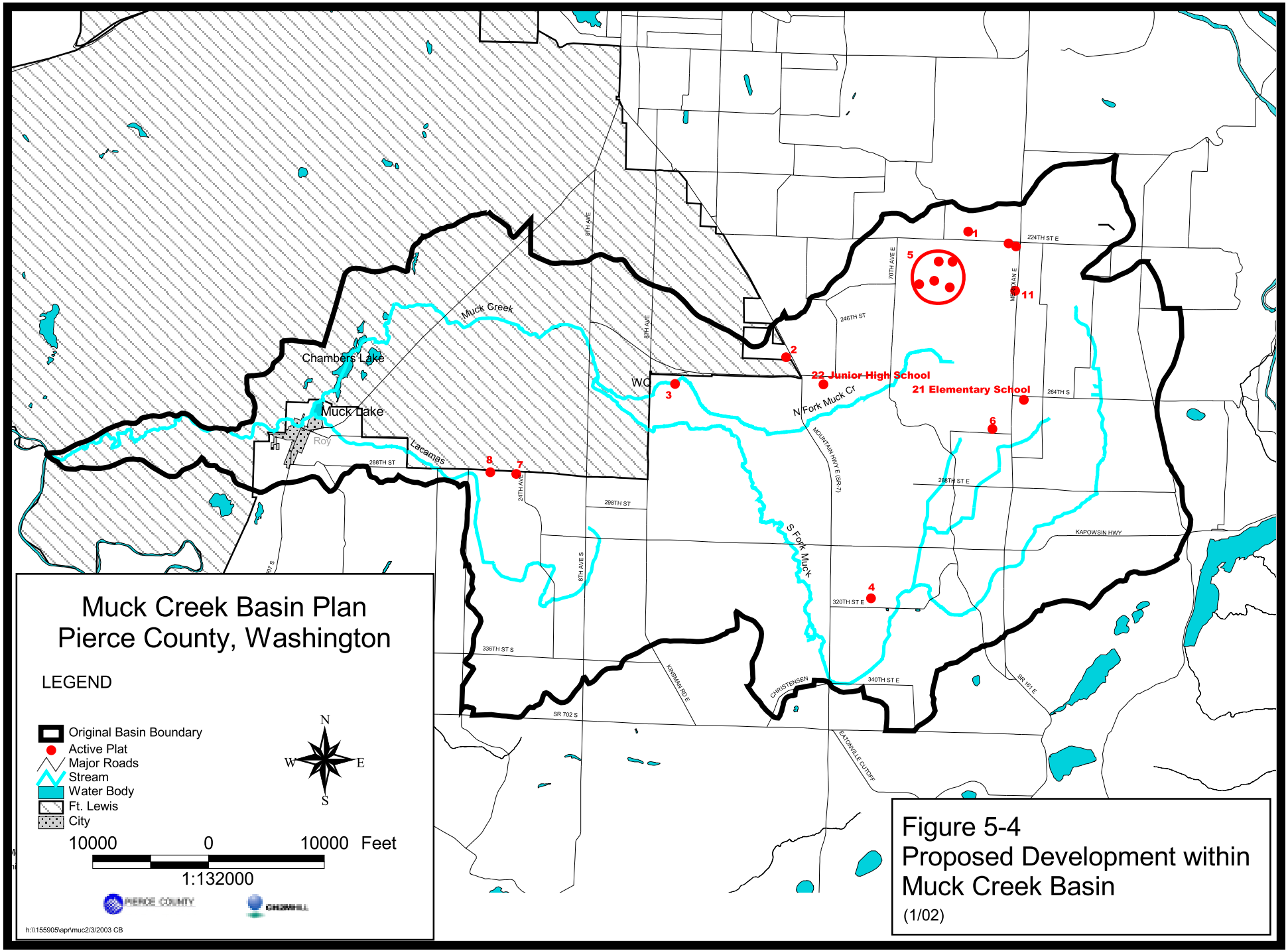


Figure 5-4
Proposed Development within
Muck Creek Basin
(1/02)

PART 2: Basin Plan Analysis

CHAPTER SIX

Flooding Problems

6.1 Flood and Drainage Problems within the Basin

The Muck Creek Basin is generally rural in nature. Impervious area within the Muck Creek Basin averages only 6-11 percent. Most of the flooding problems stem from development which has diverted runoff, causing downstream problems, or development within the flood prone areas, particularly local depressions.

Two types of flooding problems exist in the Basin; public flooding problems which are generally flooding of public roads or facilities, and private flooding problems occurring on private property. In some cases, there is a combination of the two.

Two large storm events occurred in 1996 and 1997. These events in combination with antecedent conditions caused a number of drainage complaints from Pierce County residents. Several roads were overtopped where culverts underneath the roads were not able to pass the high flow rate of stormwater runoff, or the roads were not high enough to stay above the water surface. In addition, private property was flooded and property was damaged.

The Pierce County Water Programs Division receives, investigates, and documents flooding problems and drainage complaints. The County file for drainage complaints within the Muck Creek Basin was reviewed and investigated to determine the severity of the problem.

The County drainage complaint file contained 127 individual complaints that were reviewed. In some cases, multiple complaints were associated with the same problem and were grouped together. A total of 69 drainage problems were identified from the complaint file and numbered 1 through 69 (*Figure 6-1*).

The 1991 Storm Drainage and Surface Water Management Plan (Montgomery Engineers 1991) identified 12 culverts for replacement. Five of those 12 were ranked as high priority. These assessments were based primarily upon a hydrologic model analysis which indicated potentially undersized culverts in the Muck Creek Basin. During Phase 1 of the current basin planning process, a broader effort was made to identify drainage or flooding problems meriting further analysis during Phase 2. This included interviews with County maintenance staff, input received during public meetings and observations made in the field. Additional problems in need of investigation were identified. It was determined that the five high-priority projects in the 1991 Plan merited further analysis. However, there was no indication that the remaining culverts posed any substantial drainage or flood problems in the field and they were not considered further. The problems identified in Phase 1 are numbered 101 though 115 and are also shown in *Figure 6-1*. (This includes 102 and 102A, thus numbering 16, in all.)

The four-tier process listed below was used to gather enough information about each complaint to determine the extent of the problem.

1. Phone calls were made to all the drainage complainants
2. If the phone number was missing or incorrect, letters were sent to the recorded addresses
3. Site investigations were conducted at all of the locations identified in the complaints
4. If no one was at home at the time of the site investigation, a letter was left at the property, particularly if no response was received from the above three steps

When enough information was obtained from the known problem areas to make a determination as to the action needed to resolve the problem, the problems were assigned to one of the seven categories listed below. Refer to "Appendix K: Drainage Complaint Investigation Summary" for a complete listing.

- Recommended Capital Improvement Project (CIP) – A project is identified to address the problem. Maintenance of an existing drainage structure may also be required – Number of problems reported: 24
- County Maintenance – An existing drainage structure in need of maintenance – Number of problems reported: 8. The County has an ongoing maintenance program. A list of these maintenance needs has been transmitted to the County via a memo.
- County Closure – A previous complaint resolved by Pierce County Surface Water Management Division – Number of problems reported: 8
- Recommended Closure – The problem has been resolved or is a private-property matter – Number of problems reported: 31
- More Detailed Data or Analysis Necessary – More detailed information or study needed to identify a problem solution – Number of problems reported: 2
- Insufficient Information on the Problem – There is insufficient information on either the location or the extent of the problem to perform an evaluation – Number of problems reported: 9
- Out of Muck Creek Basin – Complaint or problem does not occur within the Muck Creek Basin – Number of problems reported: 3

The flooding problems categorized under "Recommended CIP" are listed in *Table 6.1*. The CIPs are identified for problem areas where action is needed to eliminate or reduce the drainage or flooding problem. For each recommended CIP, a preliminary engineering analysis was performed and a specific project is suggested.

Problems categorized under **Recommended Closure** are problems that resulted in one of the following conclusions: 1) the drainage complainant indicated that there was no longer a drainage problem; 2) County staff interviews indicated that the drainage problem had been resolved, or 3) field visit of the site by the Consultant concluded that drainage problems were private property related problems. A drainage problem was considered private when surface runoff or groundwater surfacing originated from the property itself or an adjacent private property nearby.

In some cases, there was not enough information available to adequately identify the location or extent of flooding. These drainage complaints were assigned to the category of **Insufficient Information on the Problem**. In these cases, practical information gathering methods such as calling the complainant and visiting the site were carried out, but with limited success in identifying the problem. It was typically found that:

Johnson Marsh
Shaver Lake
Muck Creek
Dailman Lake
Hamilton Lake
Chambers Lake
Exeter Springs
Lacamas Creek
North Fork Muck Creek
South Fork Muck Creek
224TH ST
MERIDIAN E
264TH ST E
70TH AVE
8TH AVE E
8TH AVE S
224TH
288TH
288TH ST
MOUNTAIN HWY E (SR-7)
WEBSTER
304TH ST
320TH ST
KAPOWSIN HWY
336TH ST
340TH ST
TISCH
KINSMAN RD
SR702
CHRISTENSEN
EATONVILLE CIRCLE

Muck Creek Basin Plan
Pierce County, Washington

Legend

Drainage Investigation Sites

- RECOMMENDED CIP
- COUNTY MAINTENANCE
- COUNTY CLOSURE
- RECOMMENDED CLOSURE
- FURTHER REVIEW NECESSARY
- INSUFFICIENT INFORMATION ON THE PROBLEM
- INVESTIGATION
- Water Body
- Tributary Ditches
- Creek
- Roads
- Railroads
- Ft Lewis
- Basin Boundary-Original

N
W E
S

PIERCE COUNTY
CH2MHILL

6000 0 6000 Feet

\\simba\PROJ\155905\GIS_gen\apr_gen\drainage_complaints.apr 1/13/03 DMG

Figure 6-1
Drainage Investigation Sites

1. The individuals who made the initial drainage complaint no longer resided at the address;
2. The present owner, having moved in after the major storms of 1996 and 1997, was unaware of flooding problems;
3. On-site visits by the Consultants did not clearly identify problem areas; and
4. County staff had no further information to aid identification of possible flooding problems.

In the future, after a severe storm, the County may wish to re-visit these sites to more directly determine the extent of flooding at these locations.

6.2 CIP Modeling and Analysis

The Pierce County Stormwater Management and Site Development Manual (originally adopted by Pierce County by Ordinance 96-46S2), effective November 3, 1997 and as amended thereafter, was used as a basis for the analysis and conceptual design on the Recommended CIPs. Each recommended CIP has been assigned a code which gives information on the location and the type of CIP (refer to "Appendix L"). The CIP # and the Problem # (in parentheses) are shown. These are also mapped in *Figures 10-1* and *6-1*, respectively. Note that a number of problem areas shown in *Figure 6-1* are grouped together for a common solution.

Several flooding problems are associated with roadways overtopping due to insufficient capacity of the culverts carrying flow beneath them. These five culvert crossings are listed below.

- CIP12LC-CULO1 (101): Northern-most Lacamas Creek crossing of Schudy Rd S
- CIP12SF—CUL03 (102A): Drainage to South Creek crossing of 288th St E (east of Meridian E)
- CIP12SF-CUL01 (33/102): East Fork of South Creek crossing of 288th St E (east of Meridian E)
- CIP12SF-CUL04 (103): Drainage to South Creek crossing of 288th St E (west of Meridian E)
- CIP12SF-CUL05 (104): West Fork of South Creek crossing of Meridian E (north of 288th St E)

The drainage basins contributing to the culverts were delineated and the geometric information of the existing culverts was obtained. Flooding problems related to insufficient capacity of existing culverts, were analyzed based on the 100-year, 24-hour storm event as required by the Pierce County Stormwater Management and Site Development Manual for natural streams. A HEC-1 model created by Montgomery Engineers in 1991 was modified to estimate the expected 100-year flow rate through the culverts.

Aerial photographs from 1990 and 1999 were used to compare land-use and land cover within each sub-basin draining to the culvert being analyzed. In all cases the land cover had not significantly changed from 1990 conditions used for the modeling done in the earlier Montgomery analysis. Future zoning in each sub-basin is low-density. Therefore, the 1991 model input parameters for land cover were used for the present analysis.

The culverts were analyzed using the Federal Highway Administration's HY8 model to assess the current performance. The model was then used to select a culvert size and material sufficient to pass the 100-year flow rate; complying with Pierce County stormwater facility standards.

6.2.1 CIP12NF-CUL03 (24/113)

252nd St E experiences frequent shallow flooding. This road crosses the upper portion of the North Fork of Muck Creek. There are two culverts underneath 252nd St E that drain water from the large wetland north of the road. The drainage basin contributing to the culverts was delineated. The Montgomery HEC-1 was used to estimate the expected 100-year flow rate. A profile of the road and culverts was obtained during field reconnaissance and calibrated to the topographic information provided by Pierce County. A basic HEC-RAS hydraulic model was created to analyze the performance of the two culverts.

6.2.2 CIP12NF-INF01 (17) AND CIPMS-INF01 (51/106/107)

Two areas have been identified as having similar flooding problems in the North Fork- Muck Creek Sub-Basin. The analysis performed was similar for both cases. The first problem (Site 17) was identified during the 1996 storm event by residents on the private road 242nd St E. The road became flooded as well as some private property. No outlets for accumulated runoff exist. The second problem area (Site 51/106/107) is a large drainage area in the vicinity of 288th St S, west of 8th Ave S. A large drainage channel through two private properties drains to a culvert under 288th St S that terminates in a shallow-ponding area on Fort Lewis property with no outlet. Both the road culvert and upstream drainage channel tend to back-up under higher rainfall conditions. 288th St S is flooded during periods of most winters.

The drainage basins contributing to both problem areas were delineated and aerial photographs were used to establish the current land cover. The drainage areas contributing runoff to Sites 17 and 51/106/107 are 56 and 332 acres, respectively. The Department of Agriculture Soil Survey for Pierce County was used to determine the soil characteristics and the hydrologic soil groups within the drainage basins. The (continuous flow) Western Washington Hydrology Model (WWHM) developed by the Washington State Department of Ecology was used to estimate the required size for an infiltration pond at each location. A conservative long-term infiltration rate of 0.5 inches per hour based on soil type was used to size the infiltration ponds as required by the Washington State Department of Ecology Stormwater Management Manual for Western Washington.

6.2.3 CIP12NF-INF02 (114)

Another site that experiences shallow significant flooding is located west of the shopping center at Graham, located on the northwest corner of Meridian and 224th St E. This area lies within the upper portion of the North Fork of Muck Creek Sub-Basin, although there is no direct surface drainage from the area. Runoff from 2,440 acres is discharged west of the shopping center. This runoff spreads across several acres of undeveloped land. One small infiltration basin has been excavated in the area on the west side of the flooded area. A mobile home park lies a short distance further west.

The same type of analysis was performed for this site as for sites 17 and 51/106/107, however, the drainage Basin that contributes to the flooding area is very large and is in an Urban Growth Area. Therefore, the Pierce County Zoning map for the Basin was used to generate land cover input to the WWHM used to evaluate a regional infiltration pond.

A conservative long-term infiltration rate of 0.5 inches per hour based on soil type was used to size the infiltration ponds as required by the Washington State Department of Ecology Stormwater Management Manual for Western Washington.

6.2.4 CIP12SF-DIV01 (49/68/115)

Several residents located in the southern portion of South Creek experience flooding downstream from a large culvert under Mountain Highway E (SR 7) south of 340th St E.

The drainage Basin contributing to the culvert was delineated and aerial photographs were used to establish the current land cover. The Department of Agriculture Soil Survey for Pierce County was used to determine the soil characteristics and the hydrologic soil groups within the drainage Basin. The (single-event) Stormshed Model was used to estimate the 100-year storm flow rate through the culvert. A uniform flow analysis was performed to estimate the required size for a road-side conveyance system running along the east side of SR 7 that would convey the peak stormwater flows north, directly to South Creek.

6.2.5 CIP12SF-PIP01 (42)

Flooding has occurred on private property in the vicinity of 296th St E and 47th Ave E. A significant drainage area consisting of undeveloped land, private property, and part of 296th and 47th drains through an 18" road culvert under 47th Ave. E. The pipe daylights on the west side of 47th and then stormwater enters a private 12" pipe on private property. The private pipe drains to a catch basin located in the middle of a cul-de-sac. Stormwater flows away from the catch basin through an 18" pipe under two private properties and into a drainage channel that drains to the South Fork of Muck Creek. During large storm events, stormwater often bypasses the 12" private pipe and travels overland through the private property. In addition, the catch basin in the cul-de-sac often overtops and flows up, out of the grate. When this happens, water flows across private property.

As suggested by the Pierce County Stormwater Management and Site Development Manual, a basic backwater analysis of the existing system was performed. There was no elevation data for the catch basin and the pipe, so the backwater analysis was based on the existing 5-foot topographic information available for the area.

6.3 Potential Solutions - Capital Improvement Projects

There are 17 capital improvement projects (CIPs) recommended to address 24 drainage and flooding problems. These are listed in *Table 6.1*. Their locations within the Muck Creek Basin are shown in *Figure 10-1*. Culvert upgrades are identified at ten road crossings: two on the Lacamas, three on the North Fork and five on the South Fork or its tributaries. Two infiltration basins are recommended as solutions to local ponding of water where no nearby outlet exists for the stormwater. Two projects involve the extension of road curbs or low berms to prevent road runoff from damaging private property. Finally, a regional stormwater facility, type to be determined, is recommended for the Graham area. Conceptual design solutions were developed for each of the CIPs identified. Refer to "Appendix L" for sketches of each CIP.

The area downstream of each Recommended CIP was reviewed for known flooding problems or complaints. With the exception of CIP12NF-CUL02, none were found and it is not anticipated that the remainder of the CIPs would cause downstream flooding problems. In all cases, a detailed design will be required to permit and construct the projects. A more detailed investigation should be carried out to identify property lines, topography and soil properties to confirm the feasibility of infiltration ponds for: CIP12NF-INF01 and CIP12MS-INF01.

The Pierce County Stormwater Management and Site Development Manual and WDFW's fish passage guidance were used when applicable for design standards related to stormwater management and conveyance facilities. Generally for culverts, the maximum headwater depth should be no greater than 1.5 times the diameter of the culvert with no roadbed saturation. The minimum cover for culverts is 2 feet under roads. Culverts are be designed for the 100-year, 24-hour storm event for natural channels. Culverts in perennial sections of the creeks and those with fish potential were also subject to more rigorous design standards published by the WDFW.

6.4 Sites Requiring More Detailed Data or Analysis

Several flooding or drainage problems require a detailed topographic survey to adequately address the problem. In these cases, the existing 5-foot topographic information is inadequate to develop or complete a solution. Two of the problem sites will require a detailed hydrologic and hydraulic analysis, beyond the scope of this study, to adequately address.

6.4.1 Site 02

A cross-road culvert is proposed to relieve local ponding, routing the flow west along 216th Street E.. This road ditch eventually turns north, and flows onto private property. One neighbor stated that this ditch may be partially blocked but this issue could not be further investigated due to lack of access. Downstream investigation of this ditch is recommended. This site is recommended for a CIP (CIP12NF-CUL01) in Section 6.1.

6.4.2 Site 16

A recommended cross-road culvert will bring additional runoff to a low-lying area that may currently support a wetland. A neighboring property owner states that his property is currently flooded due to ponding in this low-lying area and the project may exacerbate this problem. A detailed topographic survey and a hydro-period analysis of the ponding water is needed to determine if the project will impact either the wetlands or the property owner. This site is recommended for a CIP (CIP12NF-CUL02) in Section 6.1.

6.4.3 Site 21

The Three Ponds Mobile Home Park suffers occasional flooding due to runoff flowing from a culvert located along Mountain Highway. The mobile home park lies along the boundary of Fort Lewis, into which this runoff flows. However, the runoff appears to pond in a shallow depression and can back up beyond the Fort boundary and onto the mobile home park property. Addressing this problem will require a detailed topographic survey of the ponding area and the cooperation of authorities from Fort Lewis.

6.4.4 Site 38

This site lies near the floodplain located near the junction of the North and the South forks of Muck Creek. Due to the flat nature of the land, it is uncertain whether this is a local ponding problem or due to flooding from the creek. The road flooding does not appear to be major problem to the local residents and there is no known house or other structure flooding in the area. If this problem was to be further analyzed, a detailed topographic survey of the local area would be needed.

Table 6.1 Recommended Drainage Capital Improvement Projects (CIP)*

CIP	LOCATION	CIP SUMMARY
CIP12NF-CUL01	216th St and 118th Ave Intersection	300 feet of ditch maintenance; install 80 feet of 12" pipe under 188th Ave. E connecting an existing dry well to an existing ditch
CIP12NF-RD01	103rd Ave. E and 238th St E	100 feet of curb extension to prevent street runoff from reaching property; additional, owner installed private drainage system recommended at the toe of embankment
CIP12NF-CUL02	242 St E and 70th Ave E	Culvert maintenance near the intersection of 242nd St E and 70th Ave E; install a100 feet of 12" culvert at the road sag on 70th Ave E just north of 242nd St. E. Conduct further drainage investigation.
CIP12NF-INF01	242nd St E, East of 46th Ave E	Construct a 6-foot deep infiltration pond on 1.5 acres with a capacity of 7.5 acre-ft. A 500-foot long ditch is needed to convey runoff to the pond. The pond would receive runoff from 56 acres which currently floods a road.
CIP12NF-CUL03	252nd St E, East of 70th Ave E	A 36" and a 48" culvert are inadequate to convey flows under this road, which frequently floods. Add 6 additional 24" diameter culvertsInstall a 12'x4' arch culvert.
CIP12SF-CUL01	288th St E, 7,200 Ft East of Meridian E	Replace three existing 36" culverts with two 7' x 8' Concrete Box Culverts, each 40 feet long.
CIP12SF-CUL02	Kapowsin Hwy and 288th St E Intersection	Ditch maintenance needed on all ditches surrounding the intersection; install a 50-foot 12" culvert under 288th St E.
CIP12SF-PIP01	296th St E and 47th Ave E	Replace existing 12" pipe with 65 feet of 18" pipe, install catch basin, install 12" culvert under 47th Ave E
CIP12SF-DIV01	Mountain Highway E, South of 340th St E	Install a flow splitter to direct high flows north to the South Fork; construct approximately 730 ft of 24" pipe to convey flow under 340th Street E. Construct a drainage ditch the remaining 490 ft to the South Fork. A second phase could include a 1-acre infiltration pond west of Mountain Highway.
CIP12MS-INF01	1200 block of 288th St S. (1,500 Ft West of 8th Ave S)	Construct an 8-foot deep infiltration pond on 5 acres with a capacity of 30 acre-ft. A 100-foot long ditch is needed to convey runoff to the pond. The pond would receive runoff from 332 acres which frequently floods 288th St S.
CIP12LC-RD01	1400 block of 336th St S. (2,200 Ft West of 8th Ave S)	Raise 1,700 feet along 336th Street S an average height of 1.5 feet to eliminate frequent flooding at a road sag. Hydrologic study and wetland survey needed.
CIP12LC-CUL01	Schudy Rd S and 311th St. S, 2,600 Ft South of 304th St S	Replace twin 36" culverts under Schudy Road with a 29-foot long 10'-11" wide by 6'-4" deep Metal Box Culvert.
CIP12SF-CUL03	11000 block of 288th St E and 113th Ave. E. (3,500 Ft East of Meridian E)	Replace existing 36" culvert under 288th St E with a 43-foot long 5' x 6' Concrete Box Culvert with a debris barrier
CIP12SF-CUL04	9500 block of 288th St E (1,750 Ft West of Meridian E)	Replace twin existing 24" culverts under 288th St E with two 44-foot long 5' x 6' Concrete Box Culverts
CIP12SF-CUL05	27900 block277th St. E and of Meridian E (3,650 Ft North of 288th St E)	Replace existing 36" culvert under meridian E with a 41-foot long 5' x 7' Concrete Box Culvert
CIP12NF-INF0XXX2	12900 block of 224th St E (1,900 Ft West of Meridian E)224th St. E and Meridian	Construct a 12-foot deep infiltration pond on 12 acres with a capacity of 115 acre-ft. This pond would receive runoff from 2,400 acres in the Graham area. Mitigation would be required for the loss of up to 0.35 acres of wetland.A regional solution for flooding problems will be developed after a study (ST12-01) has been completed to determine an appropriate solution. Stormwater currently infiltrates at an undeveloped lot, located behind a shopping center, near 224th St. E and Meridian.
CIP12LC-CUL02	Lacamas Creek at SR 507	Replace the existing culverts with a 20' x 5' concrete Box Culvert to convey the 100-year, 24-hour storm event. This project will require action by the State Department of Transportation.

*Locations are shown in *Figure 9-3*

CHAPTER SEVEN

Intermittent Flow and Water Quality Problems

Chapters 4 and 5 discuss conditions in Muck Creek and its tributaries. During the period of this Basin study, most sections of the stream have dried up at one time or another. In addition, water quality standards for temperature and fecal coliforms are frequently exceeded. Although turbidity in the creek is generally low, sedimentation problems do exist. This chapter reviews these problems and potential solutions.

7.1 Analysis of Causes

7.1.1 Intermittent Stream Flow

Intermittent stream flow conditions are extensively documented in Chapter 4. Except for a limited length along its middle lower stretch, flow in the South Fork ceases during most summers. The upper and middle stretches of the main stem of Muck Creek also go dry in most years. These conditions commonly persist for several months between mid-summer and the onset of the rainy season in October or November. During the drought year of 2000-2001, flow in the lower portion of the main stem ceased, which is a relatively rare occurrence. The only portions of Muck Creek that sustain a permanent flow are the North Fork and Lacamas Creek.

The primary cause of these intermittent stream flow conditions is natural geology of the Basin. Much of the northern and the central portion of the Basin is covered by Spanaway Soils. This glacial outwash material is highly infiltrative. As documented by the Sinclair Study (2002) (reviewed in Chapter 4) when the groundwater table drops below the level of the streambed, large amounts of stream flow infiltrate through the streambed. Losses in excess of 20 cfs per mile have been measured. Thus, the naturally lower stream flows of the summer and early fall typically cease several miles upstream of Highway 507 in the central portion of the Basin. At this time of year, only the North Fork (and to a lesser extent, Lacamas Creek) is contributing flow to the main stem of Muck Creek.

This is not a recent phenomenon. Stream flow records for Roy indicate dry stream conditions at least as far back as 1949, the oldest flow records found. Over the past several decades, flow control structures have been installed at the outlets to two lakes, upstream on Fort Lewis. As discussed in Section 5.2, water level regulation at Chambers Lake appears to have resulted in sudden declines in stream flow at Roy during June of 2000 and 2001. While it's possible that this water regulation may hasten the onset of stream desiccation at Roy, this is a condition that long predates any low dams on the Fort Lewis portion of the Basin.

Water use within the Basin was examined to determine if this might be a contributing factor to flow depletion. Water use data is presented in Section 4.4. Most of the water use in the Basin is from wells. Current domestic water use is estimated to be about 3,000 acre-ft/yr. This is projected to rise to around 4,000 acre-ft/year by 2030. The majority of the domestic water use is disposed to onsite septic systems after use. These systems discharge to the subsurface soils. Therefore, most of this water use is returned to the groundwater.

Data on agricultural irrigation in the Basin are not available. The most current irrigation data available is 2,600 acre-ft/yr for the entire Nisqually River Basin. It is conservatively assumed that 2000 acre-ft/yr of irrigation occurs within the Muck Creek Basin. This does not include water used to irrigate gardens and small pastures on residential parcels. For purposes of this analysis, an additional 2,000 acre-ft/year for rural residential irrigation is assumed. Thus domestic and irrigation water uses within the Basin are estimated to each use on the order of 4,000 acre-ft/yr. The LRI Landfill pumps out leachate collected within its landfill area. This totaled 1.8 million gallons in 2000, or about 6 acre-ft. There are no other major industrial water users in the Basin.

Overall water use in the Muck Creek Basin is estimated to be on the order of 8,000 acre-ft/yr (Table 7-1). Sinclair (2001) estimates total groundwater recharge in the Muck Creek Basin to be 120,000 acre-ft/yr. Water use within the Basin represents less than seven percent of groundwater recharge. Although not necessarily representative of the entire Basin, data from the two wells in the Basin with long term monitoring records indicate no trend of rising or declining groundwater levels (Figure 4-8). Section 5.6 indicates that future development within the Basin will not substantially change the amount of impervious surface area or water demand (Section 4.4). Therefore, future development is not expected to reduce groundwater recharge potential in the Basin or to substantially exacerbate the intermittent flow conditions of Muck Creek.

Table 7-1 Water Use in the Muck Creek Basin

Use	Amount (acre-ft/yr)
Domestic	4,000
Large-Lot Irrigation	2000
Agricultural Irrigation	2000
Industrial	<50
Total	8,000

7.1.2 Water Quality

Relatively high stream temperatures are common during the summer months. The low stream flows in much of the Basin during this time of the year are undoubtedly an important factor. However, high stream temperatures are also common in the perennially flowing the North Fork. The primary cause for these high stream temperatures is the lack of riparian shade common to most stretches of Muck creek (Section 4.6). Past agricultural and rural development practices in the Basin have resulted in the removal of trees along one or both sides of the streams. Tree frequency along the streams may be naturally low where they cross prairie areas. A lack of tree canopy allows sunlight to reach the stream surface and warm the water.

Fecal coliform violations occur relatively frequently, although the data show no evidence of gross contamination. At this time it is not possible to distinguish to what extent these violations are related to failing septic systems, horse or farm animal contributions or other sources. However, observations made during the stream surveys indicate that unfenced pastures and in several cases, nearby animal holding areas were probably major contributors. These same

practices contribute to much of the sedimentation observed in the steambed, as well. Although turbidity has not been identified as a major water quality problem in the stream, settlement of silt along the stream bottom is an important factor contributing to stream habitat degradation.

7.2 Potential Solutions

7.2.1 Intermittent Stream Flow

There are several potential solutions to the intermittent stream flow phenomenon in Muck Creek, but each has problems. Flow augmentation (addition) is commonly used elsewhere to increase summer low flows. This often has the added benefit of reducing high summer stream temperatures. However, flow losses from the main stem through the stream bottom exceed 20 cfs in the eastern portion of Fort Lewis. Flow augmentation on the order of 50 cfs, downstream of the confluence of the North and the South forks, would probably be needed to keep the main stem flowing throughout the dry season. There is no readily available source of water of this magnitude.

Another possible solution would be to line the stream channel with an impervious sub-layer that would reduce or eliminate streambed seepage. The liner could be a plastic membrane, a bentonite additive or well-compacted glacial till hauled to the site. The stream bed currently goes dry nearly each summer and early fall and this would provide a natural "window of time" for construction. However, the 6+ miles of stream construction and restoration below the North Fork would be very costly. In both 2000 and 2001, the flow in the North Fork declined to around 3 cfs from July through September. It is by no means certain that 3 cfs would be sufficient to maintain perennial flow along the 9-mile length of stream channel between the flow measurement point at 8th Avenue E and Roy, even with a lined stream channel. Minor stream losses and evapotranspiration within the lake and wetland sections downstream of Highway 509 could easily deplete this limited flow. In addition, the regional effects resulting from the loss of stream recharge to the groundwater are not known and would require further study.

In summary, the establishment of perennial flow in Muck Creek would be very costly and could have serious, unanticipated impacts. This approach is not recommended at the present time and would need further study if pursued in the future.

7.2.2 Water Quality

The water quality and sedimentation problems discussed in Section 7.1 can be addressed by an effective management and restoration program for the riparian lands bordering Muck Creek and its tributaries. Where active grazing of land occurs, exclusion or highly limited access of animals by fencing or other means is generally necessary to protect the riparian buffer on both sides of the stream. Once protected from farm animal access, native trees and other vegetation need to be planted to provide the shade and restore the natural runoff filtering function of the riparian area. These measures can reduce the amount of sediment reaching the streams as well as reduce the potential for bacterial contamination. Although it would take a number of years to adequately establish, the replanting of a tree canopy would eventually result in cooler summer stream temperatures, reducing the frequency and severity of stream temperature violations. These measures would also improve stream habitat and are discussed in more detail in Chapter 8.

CHAPTER EIGHT

Habitat Degradation

8.1 Analysis of Causes

As described in the Chapter 4, there are a number causes for salmon habitat degradation in Muck Creek. The following discussion is organized in the order of importance each limiting factor contributes to salmon production. There are likely several native non-salmonid species in Muck Creek: sculpins (*Cottus* spp.), lampreys (*Lampetra* spp.), and perhaps redside shiners *(Richardsonius balteatus)*. Conditions that are good for salmonids are also good for the sculpins and lampreys.

8.1.1 Fish Passage and Low Flow

The relatively late timing of the chum runs in the Muck Creek system suggests that the fish that utilize the creek for spawning have been influenced by the intermittent stream flow condition and have timed their runs to coincide with passable stream flows through the reach above Roy. Coho may be able to hold in the Nisqually River during a period of very low flow in Muck Creek until flows increase, at least into January. This would favor late-arriving fish. The very low number of coho in the Muck Creek system does not allow a more specific analysis. Spawning coho have not been seen in Muck Creek for several years.

The rearing requirements of coho may hinder their widespread establishment in the Muck Creek Basin under the intermittent-flow circumstances. The fact that coho must rear in a stream for 18 months and almost always return after 18 months at sea makes them less resilient to annual variations in rearing or passage conditions than chum salmon.

Chum salmon are not as vulnerable, as a population, to occasional disastrous stream flow years, such as occurred in 2000-2001. It may be that the chum spawning in Muck Creek have adapted to the unique flow conditions of this creek, a phenomenon seen in other spawning fish populations. As is typical in Puget Sound rivers, about half of the adult chum salmon from any given brood returning to Muck Creek are 3 years old and half are 4 years old. This makes them more resilient as a population to one disastrous year because half would return to spawn during a different year. The same is true, in general, for steelhead for the same reasons. However, steelhead may be less affected by intermittent flow in Muck Creek due to the fact that they return to the stream later in the year (as late as May). Since there are so few steelhead in the system (only one reported in the last 10 years), only generalizations can be made. Part of the lack of information is due to the fact that spawner surveys are not conducted at a time when spawning steelhead would be observed in Muck Creek. Steelhead in the Nisqually River system spawn from early March to mid-June. Those using Muck Creek would probably be similar. There is always at least some water in the lower portion of Muck Creek before this time. If early-arriving fish were delayed by low water, the consequences would negligible.

The winter of 2000-2001 is a good example of a disastrous year for the salmon in the Muck Creek watershed. Coho and chum were blocked at the mouth of Muck Creek due to low flow conditions for a period of time spanning the chum run. In addition, the Muck Creek reach in the

eastern portion of Fort Lewis never experienced surface flow during fall or winter. According to Nisqually Tribe biologists, this happens every few years (Walters 2002, personal communication). Salmon were unable to access habitat upstream. The more often this situation occurs, the less likely a run can be re-established above Roy. It is possible that this situation may be improved by a long series of wet years. Scientists have recently identified a loose decadal pattern of wet and dry cycles in the Pacific Northwest spanning about 22-28 years (Graham 1994). This has been shown to correlate fairly well with salmon run size in the Pacific Northwest (Anderson 2000). Wet years generally produce better juvenile survival. This leads to more returning adults, if all other factors remain constant (e.g. ocean conditions). The wet and dry cycles may be interspersed with occasional dry and wet years, respectively as occurred during the drought winter of 2000/2001.

The fish ladder at Chambers Lake on Fort Lewis is a fish passage barrier when there is no flow coming out of the lake. During periods when the lake is discharging, the operation of the fish ladder may pose a problem. The head gate controlling water flow into the ladder is manually controlled by personnel at the Fort. The flow must be inspected frequently as the lake level changes and the head gate adjusted to assure that there is sufficient flow to promote fish passage. The Fort has recently begun to keep records of flow conditions and head gate adjustments (Zuchowski 2002, personal communication). As this data accumulates, Fort personnel should be able to better evaluate the operation of the ladder to determine whether it is a barrier to salmon, at least during the time of the fish runs.

8.1.2 Channelization

Channel morphology in the Muck Creek Basin above Fort Lewis, was found to be consistently straightened and ditch-like. This is a condition common to the Muck Creek main stem above Roy, the North Fork, the South Fork, and Lacamas Creek. There was no evidence of this being done recently, but several residents made reference to dredging projects 10-15 years ago in the middle reach of Lacamas Creek. During the Great Depression Era, government-sponsored channels were constructed on several tributaries to the South Fork upstream of 304th Avenue E. However, it is likely that most of this action was taken around or before the 1920s when much of the settlement and land clearing began.

It is difficult to determine the natural channel morphology of Muck Creek and tributaries because of the extensive channelization. The channels in both the South and North forks as well as Lacamas Creek are too narrow for natural stream meandering to occur. As a result, corner pools (pools created by meandering alone) are rare and habitat complexity is low During the stream surveys, a reach was found in the South Fork which had a floodplain about twice as wide as the average width for the rest of the South Fork (45 feet vs. 22 feet). At that location, there were a series of corner pool and riffles. The pools were large and deep. It is believed that this represents the natural morphology of the South Fork, North Fork, and Lacamas Creek. Of course these dimensions would be different for these tributaries in proportion to their discharge and slope. Downstream on the South Fork/North Fork confluence, one would expect an even wider active channel, as the combined discharge would be greater than that of each tributary.

8.1.3 Riparian Vegetation and LWD Removal

Natural riparian communities and Large Woody Debris (LWD) are an important part of salmonid ecosystem function in Puget Sound lowland streams such as Muck Creek. Mature riparian vegetation provides shade to keep summer temperatures down. High summer temperature is one of the most common limiting factors in the region. This is true for Muck Creek as well.

Riparian vegetation also supports terrestrial insects which serve as food for fish and other animals. Riparian vegetation provides leaf and needle materials which also support aquatic food chains. Tree roots stabilize stream banks and promote channel complexity. Channel complexity, including an abundance of pools, is an important feature of quality salmonid habitat. Trees growing near the stream eventually get undercut by stream channel migration and fall into the channel creating additional channel complexity. As trees mature, they become more susceptible to blow-down and fall into stream channels as LWD.

Trees in most of the riparian zones of the Muck Creek Basin upstream of Fort Lewis are fairly young. This characteristic feature is nearly universal throughout the North Fork and South Fork of Muck Creek as well as in the Lacamas Creek subbasin. In most cases, alder and maples appear to be 20-30 years old. Alder live 40-80 years depending on conditions, while maples live longer. In some cases, nearby trees outside of the riparian zone were older, suggesting that the riparian trees were removed for channelization purposes. In other cases, the young trees were in a very narrow band (one tree width) bordering pasture. This would suggest that trees and vegetation were removed during general land clearing (perhaps in combination with channelization) and allowed to reestablish only in a very confined area. This results in lower LWD recruitment potential and allows livestock grazing to occur closer to the stream. Apparently, conifers were not replanted and only deciduous trees with wind blown seeds became reestablished. Deciduous trees provide lower quality LWD in streams because they rot faster and are generally smaller than conifer LWD. In the few reaches where older conifers are present in the riparian community, and especially when older cedars dominate, habitat quality was found to be significantly better than reaches bordered by deciduous species. At least part of this higher habitat quality is due to the size and quality of the instream LWD found in conifer-dominated reaches.

As a whole, the upper Muck Creek Basin is devoid of instream LWD. As a result, channel complexity is generally poor and pool abundance and quality is low. It is obvious that LWD is actively being removed from stream channels. Local residents encountered during stream surveys often spoke of the ongoing need to keep the channels clear of debris to prevent local flooding. There was evidence of LWD removal as well. The young age of the trees in most riparian areas will severely limit the natural replacement of these instream materials for many years to come.

8.1.4 Cattle and Horse Ranching Practices

Sedimentation is a problem in Muck Creek. While it is probable that some of the sediment load is coming from new residential development, no evidence of this was observed during stream surveys. Sediment was, however, very strongly associated with cattle ranching, and to a much lesser degree to horse ranching practices. Stream reaches immediately downstream of cattle ranches were always choked with sediment. The degree of impact is strongly related to grazing pressure and to animal access to the channel. For instance, one ranch on the North Fork, which had relatively low grazing pressure but free cattle access, was found to have sediment problems in the first pools downstream and moderate impact to the gravels in riffles within the grazed reach. There were a few exposed cut banks but they were limited in extent. Another ranch on upper Lacamas Creek was heavily grazed, with free cattle access. The stream channel through this area was heavily impacted. The banks were collapsed and bottom substrate was composed entirely of silt. The sedimentation problem continued for hundreds of yards downstream. There were intermediate examples where there was less apparent cattle access or pressure and variable stream impact. It is obvious that much could be accomplished with a program of fenced enclosures.

8.1.5 Reed Canary Grass

Reed canary grass has been identified as a serious problem to salmon habitat as well as the more obvious problem it poses to cattle pasture quality, since it is not very nutritious forage. Reed canary grass is able to out-compete everything else once it becomes established. Trees such as alder, maple, cottonwoods, conifers and others will not germinate seeds in the dense mats of vegetation. Since reed canary grass grows so fast and tall, it can shade-out many herbaceous and shrub species. The high tolerance of reed canary grass for water allows it to grow very densely in stream channels, choking them. The reduced velocity resulting from these grasses in or bordering the channel promotes sediment deposition within and upstream of the plant mass. This decreases the water conveyance capacity of the channel and thus promotes flooding. Since reed canary grass precludes other riparian vegetation, it reduces LWD recruitment, stream shading and habitat complexity. Some stream reaches were observed to be so thick with grass that salmon passage was likely impossible.

8.1.6 Development/Water Quality

As discussed previously in Chapters 4 and 5, development within the Muck Creek Basin ranges from 5 to 12 percent impervious surface, depending on location (Figure 8-1). Rural areas typically have less than ten percent impervious land cover. The work of May and Karr has demonstrated that biological impact starts to occur at a threshold of about 6 percent (May et al. 1997), based on the Benthic Index of Biological Integrity (B-IBI). Based upon the low degree of impervious area alone, one would expect B-IBI scores in the Muck Creek system to be in the "good" category (between 32 and 38). However, scores from ten samples obtained over two years ranged from 18 to 30 (Table 4-9), indicating poor to fair conditions. B-IBI scores, which include a number of Macroinvertebrate community relationships, are affected by water quality, sedimentation, peak flow scouring (bed load movement), organic debris quantity (and type), and shading. The stream gradient is mild. There is little evidence of channel erosion or substantial bedload movement, so other factors are probably at play. The water quality parameters evaluated for this study did not indicate problems for aquatic insects commensurate with the relatively low B-IBI scores, although organic pesticides and heavy metals were not measured. The most probable explanation is sedimentation associated with cattle and horse grazing. Much could be accomplished with increased riparian buffer width and limited livestock access to stream channels. Other sources of fine sediment include residential and other development close to stream channels, road crossings, and untreated stormwater inputs.

8.1.7 Culverts

Classic fish passage problems such as poorly engineered culverts, are not an issue within the Basin. All of the culverts examined during the course of the stream field reviews were determined to be passable. Culverts were assessed for fish passage using Washington Department of Fish and Wildlife (2000) Level A criteria. Level A criteria includes culvert outlet drop, culvert slope and culvert/channel width ratio. A few culverts may be a problem during flood flows due to high velocity flow, but these are only temporary blockages.

Muck Creek Basin Plan
Pierce County, Washington

LEGEND

- Original Basin Boundary
- Major Roads
- Railroads
- Stream
- Water Body
- Township and Range
- Sections
- Fort Lewis
- City
- Basin Reach

Percent Impervious Area by Reach-Original

- 5 %- 6.9%
- 7% - 9.9%
- 10% - 13.1%

N W E S

3000 0 3000 Feet

1:72000

PIERCE COUNTY

CH2MHILL

h:\\155905\apr\muckcr.apr 2/3/03 CB

T18N

R2E

R3E

Muck Creek

N Fork Muck Cr

S Fork Muck

Chambers Lake

Muck Lake

Lacamas

Rov

8TH AVE

70TH AVE E

MERIDIAN E

224TH ST E

246TH ST

264TH ST

288TH ST

288TH ST E

24TH AVE

8TH AVE S

MOUNTAIN HWY E (SR-7)

KAPOWSIN HWY

320TH ST E

340TH ST E

336TH ST S

TISCH RD S

KINSMAN RD E

CHRISTENSEN

SR 702 S

EATONVILLE CUT

M30 M25 M20 M15 M35 M40 MN5 MN10 MN20 MN25 MN30 MN15

MSS30 MSS25 MSS20 MSS15 MSS10 MSS5 MSN20 MSN15 MSN10 MSN5

ML5 ML10 L5 L10 L15 L20 L40 L30 L35 L25

MS5 MS10 MS15 MS20 MS35 MS25 MS30

Figure 8-1
Impervious Area Coverage
in the Muck Creek Basin
(10/01)

PART 3: Muck Creek Basin Plan

CHAPTER NINE
Basin Plan

This Chapter contains the Muck Creek Basin Plan, which is based upon the Basin characteristics described in Part 1 and the problem analysis of Part 2. This Chapter provides:

- A Summary of the Plan;
- Plan Approach to Basin Needs; and
- Specific Recommendations

This Chapter establishes the direction the Water Programs Division will take within this Basin to achieve its goals of flood reduction, habitat improvement, water quality improvement, ensuring responsible use of public resources, and provision of guidance for new development.

9.1 Plan Summary

The 2003 Muck Creek Basin Plan is a comprehensive guide to surface water management in the Muck Creek Basin. It focuses on multiple aspects of surface water management, including water quality, flooding, and habitat issues. In summary, the goals of the Muck Creek Basin Plan are:

Goal 1) Reduce flood hazards
Goal 2) Improve water quality
Goal 3) Improve fish and wildlife habitat
Goal 4) Coordinated and responsible use of public resources
Goal 5) Influence location and methods for new development

The Plan contains numerous capital facility projects and programmatic actions to address flooding, water quality and stream habitat problems. Several of the measures address multiple issues. For example, culvert replacements can both reduce flood hazards and improve fish passage. The establishment of a riparian buffer may displace animal grazing immediately adjacent to a stream, decreasing nutrients and reducing flood hazards. Implementation of a restoration project also provides an opportunity for public education and outreach.

9.1.1 Capital Improvement Projects

There are a total of 21 CIP's proposed in this Plan. Their locations are shown in Figure 9-2. Their distribution by problem type is shown below.[1]

- Road Flooding - 11
- Other Drainage Problems - 8
- Water Quality - 10
- Stream and Riparian Habitat - 9

CIP's involving riparian or wetland revegetation or restoration will require substantial maintenance during the first two to five years after planting. Irrigation may be required for the first year or two to establish some of the tree and brush species. In addition, annual weed removal or suppression will also need to occur at least annually until the plants are well established. This is particularly critical in areas where reed canary grass is being replaced. These additional expenditures are not included in the cost estimates.

9.1.2 Programmatic Measures

In addition to the capital construction projects, the Basin Plan recommends nine programmatic measures. They include a combination of programs that would be specific to the Muck Creek Basin and programs that would be undertaken Countywide:

- Conduct a Low Impact Development Pilot
- Adopt Updated Stormwater Management Standards
- Increase Inspections for Compliance with Stormwater Requirements and NPDES Permit
- Develop and Implement a Land Acquisition Program for Riparian and Wetland Habitat and Flood Hazard Reduction
- Develop and Implement a Program to Enhance Degraded Riparian Habitat and Water Quality and Provide Flood Hazard Attenuation
- Develop and Implement an Education, Outreach, and Technical Assistance Program
- Develop and Implement a Surface Water Management Monitoring Program
- Develop and Implement a BMP Manual for Pierce County Surface Water Maintenance Activities
- Develop and Implement an Invasive Species Management Program

The CIP and programmatic measures have been individually ranked according to a common ranking system used by all the basin plans for Pierce County. Each of the potential capital improvement projects and programmatic recommendations were evaluated using a spreadsheet that assigned points for the project/program's potential for various aspects of flood reduction (approximately 35% of total score), water quality protection or improvement (30%), natural resource improvement (30%), and other factors such as multiple use, education, and recreation

[1] The number of problems addressed exceeds the number of actual projects because of a single CIP may address multiple problems.

(5%). Each project and program was reviewed and scored using approximately 40 specific criteria. This ranking system is described in "Appendix M." This appendix also contains a spreadsheet summarizing the scores assigned to each CIP. An individual score sheet is included for each programmatic measure.

Recommended projects and programs were then put in rank order, based on their numeric benefit score, and grouped in descending order. Then, high, medium, or low status was assigned as follows:

- High Priority: 25% of total number of recommendations
- Medium Priority: 50% of total number of recommendations
- Low Priority[2]: 25% of total number of recommendations

After this order was established, projects and programs were ranked within their priority category from lowest cost to highest cost. This was done to direct County financial resources to where they do the most good for the financial resources invested. The prioritized list of measures is shown in Table 9-1. Prioritized measures recommended in the Plan over a ten year period total $10.5 million. This includes $9.12 million for capital improvement projects and $0.63 million for programmatic recommendations. Of that amount:

- $3.5 million is for projects identified as "High Priority"
- $6.5 million is for projects identified as "Medium Priority"
- $0.5 million is for projects identified as "Low Priority"

9.1.3 Information Gaps

In addition to the projects and programmatic recommendations, four basin specific studies are proposed as part of the Basin Plan (numbers 31-34, Table 9-1):

- Evaluate Groundwater Flow between Muck Creek and Clover Creek Basins in the Graham Area
- Identification of Flooded Depression Areas (Potholes)
- Detailed Flood Study along the South Fork of Muck Creek upstream of Mountain Highway

Their combined cost is $0.28 million. These studies will provide needed information to address Basin issues. The studies were not included in the prioritization process.

The total estimated cost to implement the Basin Plan is $10.03 million.

[2] Note: "low priority" does not mean "no benefit" for flood control, water quality protection, or natural resource protection. All of the recommendations in the Basin Plan provide a net benefit to these objectives. "No benefit" proposals were screened out prior to preparation of the Plan. "Low Priority" means that the proposed project or program scored lower that other projects and programs, based on the net environmental benefits that would occur from the project or program as determined by the score sheet criteria. Some projects that are ranked "medium priority" or "low priority" will be considered for implementation prior to other projects to ensure the full benefits of other projects, such as upstream fish habitat improvements are synchronized with downstream barrier removal.

Table 9-1
Prioritized List of Proposed Projects – Muck Creek Basin 2003

	Project Name	CIP Number	Score	Est. Cost	Priority Ranking	Total Costs
1	Adopt updated stormwater mgt. standards	PG00-02	380	$ 1,000	High	
2	Maintenance BMP Manual	PG00-08	427	$ 7,000	High	
3	Invasive Species Management	PG00-09	420	$ 7,000	High	
4	Implement riparian land acquisition pgm.	PG00-04	389	$ 9,000	High	
5	Implement education/tech. assistance pgm.	PG00-06	397	$ 111,000	High	
6	Increased inspections	PG00-03	398	$ 204,000	High	
7	Lacamas Creek Habitat Restoration	CIP12LC-STR01	375	$ 1,444,000	High	
8	North Fork Habitat Restoration	CIP12NF-STR01	380	$ 1,748,000	High	
	Subtotal					$3,531,000
9	Implement riparian & WQ enhancement pgm.	PG00-05	325	$ 34,000	Medium	
10	288th St E Culvert Replacement II	CIP12SF-CUL03	165	$ 41,000	Medium	
11	Meridian E Culvert Replacement	CIP12SF-CUL05	195	$ 46,000	Medium	
12	Conduct a low impact development pilot	PG12-01	346	$ 100,000	Medium	
13	Schudy Rd S Culvert Replacement	CIP12LC-CUL01	175	$ 100,000	Medium	
14	288th St E Culvert Replacement I	CIP12SF-CUL01	180	$ 128,000	Medium	
15	288th St E Culvert Replacement III	CIP12SF-CUL04	170	$ 133,000	Medium	
16	Implement surface water monitoring pgm.	PG00-07	244	$ 158,000	Medium	
17	252nd St E Conveyance Improvements	CIP12NF-CUL03	155	$ 179,000	Medium	
18	288th St S Infiltration Pond	CIP12MS-INF01	115	$ 297,000	Medium	
19	336th St S Grade Change	CIP12LC-RD01	150	$ 303,000	Medium	
20	Highway 507 Culvert Replacement	CIPLC-CUL02	215	$ 345,000	Medium	
21	South Fork Habitat Restoration	CIP12SF-STR01	365	$ 608,000	Medium	
22	Patterson Springs Acquisitions	CIP12NF-ACQ01	265	$ 1,500,000	Medium	
23	Graham Regional Stormwater Facility	CIP12NF-XXX	200	$ 2,500,000	Medium	
	Subtotal					$6,472,000
24	238th St E Conveyance Improvements	CIP12NF-RD01	45	$ 2,000	Low	
25	216th St Conveyance Improvements	CIP12NF-CUL01	45	$ 4,000	Low	
26	Kapowsin Highway Conveyance Improvements	CIP12SF-CUL02	85	$ 10,000	Low	
27	47th Ave E Conveyance Improvements	CIP12SF-PIP01	60	$ 34,000	Low	
28	70th Ave E Culvert Improvements	CIP12NF-CUL02	100	$ 39,000	Low	
29	242nd St E Infiltration Pond	CIP12NF-INF01	85	$ 136,000	Low	
30	Mountain Highway Conveyance Improvements	CIP12SF-DIV01	95	$ 319,000	Low	
	Subtotal					$544,000
31	Graham Groundwater Flow	ST12-01		$ 205,000	Not Prioritized	
32	Identification of Potholes	ST12-02		$ 90,000	Not Prioritized	
33	South Fork Flood Study	ST12-03		$ 60,000	Not Prioritized	
34	Wetland Site Identification	ST12-04		$ 70,000	Not Prioritized	
	Subtotal					$425,000
	Total Estimated Cost of Plan Implementation					**$10,972,000**

9.1.4 Implementation Strategy

Implementation of the recommended actions will generally follow the prioritization groupings of high, medium, and low and a logical order of sequencing. To ensure that the full benefits of all projects are realized, implementation will not follow the exact sequence of the first project to the last project in the High category, followed by the first action in the Medium category, and so forth. Several factors exist that will result in implementation of actions that are not in the exact sequence as depicted in the projects and programs prioritized by the benefit and ranked by cost table. These factors include the following:

- Available funds;
- Contingent projects[3];
- Available staff and professional service needs;
- Cooperation from private landowners;
- The best implementer may be an agency other than Pierce County Public Works and Utilities; and
- New information, regulations or emerging issues.

Economic Development Criteria

Implementing projects and programs recommended in the Basin Plan is expected to reduce flood hazards, and preserve or protect water quality and floodplain habitat. Collectively and individually, these projects are aimed at protecting Pierce County's quality of life. Projects and programs in the Plan will afford resource protection as the community develops; preserve, enhance or protect natural floodplain functions; balance structural and nonstructural approaches; reduce potential County environmental liabilities; and help achieve environmental compliance and long term sustainability. Collectively, these attributes help make Pierce County a liveable community where quality of life issues will provide indirect, passive economic development benefits to businesses and individuals looking to locate or stay in Pierce County.

In addition to the above, Water Programs will consider the following criteria in developing its annual proposed capital facilities plan updates:

- Is the project located in an employment center zone (or handle flow from those zones)?
- Is the project located in another type of commercial zone (or handle flow from those zones)?
- Will the project reduce permitting timelines for industrial/commercial projects?
- Will the project assure access to an employment center via road and /or rail?
- Will the project increase the supply of developable property?
- Will the project reduce overall development costs?
- Are there partners willing to contribute to the development costs of the project?
- Does the project allow / provide for land development?

In light of these and other factors, following action on the Basin Plan, Pierce County will develop an implementation strategy designed to sequence, schedule and assign resources for the various recommended actions. This implementation strategy will be developed in collaboration

[3] Contingent projects include projects such as stream restoration projects intended to reduce flood hazards and improve aquatic habitat, and culvert replacement projects intended to improve fish passage. These projects will provide their full benefit after all downstream fish passage barriers are removed, and should be sequenced accordingly.

and coordination with other potential implementers and in consideration with available financial and staff resources. The implementation strategy will include performance measurements and provide for periodic evaluation of progress.

9.1.5 Pierce County's Basin Plan Objectives

When the Pierce County Basin Planning Process was established in 2000, several objectives were identified for each basin. The 1991 Storm Drainage and Surface Water Management Plan and this Basin Plan were compared to those objectives.

Table 9-4 summarizes the degree to which the Muck Creek Basin Plan and the 1991 Plan meet the Basin Plan objectives (see "Appendix O").

TABLE 9-4
Comparison between Muck Creek Basin Plan and the 1991 Storm Drainage and Surface Water Plan: Effectiveness in Meeting Objectives

	Objectives (see Section 1.3)	Muck Creek Basin Plan	1991 Plan
Goal 1 Flooding	Incidents of property loss and repeat damage are reduced.	A	a
	Streams will not be adversely impacted by flood events.	B	c
	Pierce County's standing under FEMA Community Rating System is improved.	A	b
	New development is located outside of flood prone areas.	B	b
Goal 2 Habitat	Number of stream miles available for wild, native fish populations is increased.	A	c
	Population numbers of species listed as endangered or threatened under the Federal Endangered Species Act are maintained or increased.	A	c
	Quality and quantity of available wetland, riparian and upland habitat is improved.	A	c
Goal 3 Water Quality	State Surface Water Quality Standards (WAC 173-201a) are met or exceeded.	A	
	Number of impaired (303d listed) water bodies is reduced.	n/a	n/a
	Pierce County is in compliance with its NPDES permit for stormwater by meeting permit terms and conditions to the maximum extent practicable.	A	c
	Risk of groundwater contamination is reduced.	B	c
	Rates of erosion are reduced.	A	b
Goal 4 Public Resources	Cost of maintaining stormwater facilities are reduced.	B	
	Project value is favorable when measured against costs and benefits.	A	b
	Polls demonstrate that public awareness of flooding, habitat and water quality issues has increased.	B	
	Monitoring and enforcement programs demonstrate an increase in services per dollar spent.	B	c
	Basin Plan implementation also implements elements of other Pierce County plans.	A	
Goal 5 Developmen	New development in flood prone, riparian or significant habitat areas is prohibited.	B	
	Low Impact Development techniques identified and widely used.	A	c
	Effective BMPs identified and widely used.	A	

a) Specifically addressed; CIP's and/or measures proposed to achieve the objective.
b) Generally addressed; few or no Basin-specific measures.
c) Not addressed.
n/a) Not applicable.

9.2 Plan Approach to Basin Needs

The following describes Plan approaches to the problems identified in Chapters 6-8. These include:

- Stormwater Impact Mitigation through Low Impact Development
- Fish Habitat Protection
- Compliance Assurance
- Land Use Management
- Critical Areas Conservation
- Public Education and Involvement
- Flood Hazard Management
- Water Quality Management
- Reed Canary Grass Management
- Riparian Corridor Management
- Instream Habitat Improvement
- Livestock/Riparian Interactions
- Filling Information Gap
- Stakeholder Involvement

9.2.1 Stormwater Impact Mitigation through Low Impact Development

Low Impact Development combines site planning with individual BMP's to preserve natural drainage features and to encourage retention and infiltration of stormwater on the site. Low Impact Development (LID) practices can be effective in substantially reducing the rate and the volume of stormwater runoff from medium and high-density areas. LID emphasizes protection and use of on-site natural features integrated with small-scale (less expensive) stormwater controls to manage stormwater and maintain or restore pre-development watershed hydrologic functions. LID strategies focus on evaporating, transpiring and infiltrating stormwater on site through native soils, vegetation and bioengineering applications, rather than conveying stormwater through the use of large stormwater facilities, pipes, and other costly, traditional drainage systems. LID can reduce development infrastructure and, therefore, development costs in many settings. In addition to reduced infrastructure costs, LID practices have other attractive economic benefits that can increase a development project's marketability. LID stormwater facilities can be easier and less costly to maintain over time, and facility retrofits can be cost-effective. Developers using LID concepts can reduce the size of their stormwater ponds, resulting in more developable land.

The basic strategies to plan and implement Low Impact Development include (Hinman, 2001):

- Assess the site's current and native vegetation cover, wetland areas, soils, streams, ponds, and other critical areas. Establish buffers and delineate protected areas.
- Maximize retention of native vegetation to intercept, evaporate and transpire precipitation.
- Preserve permeable, native soils and restore disturbed soils with compost and other amendments to infiltrate and store stormwater.
- Retain and incorporate topographic site features that promote infiltration and storage of stormwater.

- Direct the location of buildings and roads away from critical areas and soils that can effectively infiltrate stormwater.
- Minimize building footprints, and road widths and lengths to reduce impervious surfaces. Eliminate effective impervious surfaces that flow directly to offsite stormwater pipes.
- Utilize pervious surfaces (e.g. pervious pavement and gravel systems) where possible to promote stormwater infiltration.
- Utilize small, de-centralized bio-retention areas with appropriate vegetation to infiltrate, store and transpire precipitation.
- Reduce the reliance on traditional conveyance and pond technologies to manage stormwater quality and quantity.
- Manage stormwater as close to its origin as possible.

Below is a sample of some potential LID site design applications and BMPs (Wulkan, 2001):

- Developers using LID set aside all sensitive areas and natural drainage, such as streams and wetlands. Portions of a site's trees and other native vegetation is also set aside.
- Specially designed bio-retention areas (or landscaped rain gardens) can capture, filter and infiltrate stormwater.
- Impervious areas can be reduced by designing narrower roads and using permeable pavement for parking lots and driveways. Pervious pavement can help to infiltrate and treat surface water runoff at the site.
- Runoff from remaining impervious surfaces, such as rooftops, can be directed onto vegetated areas with porous soils.
- Rooftop designs can include roof gardens, which further retain and slowly release stormwater.
- Soils compacted during construction are amended with compost or other organic material to restore their capacity to infiltrate runoff and grow healthy plants.

The County has revised its stormwater manual and development regulations to include LID practices. The new Washington Department of Ecology *Stormwater Management Manual for Western Washington* (Washington Department of Ecology 2002) also emphasizes the use of LID strategies wherever practicable.

In addition to more effectively managing stormwater, Low Impact Development strategies can have other environmental and community livability benefits as well. Infiltrating stormwater on site helps to recharge local groundwater supplies. Much of the northeast portion of the Basin, where housing development is occurring, has soils suitable for stormwater infiltration. LID road designs result in narrow streets that reduce traffic speeds, increasing public safety and promoting walking and bicycling as alternative transportation methods. Subdivisions and commercial areas can be designed to promote interaction between neighbors and to incorporate open space and recreational areas. Clustered housing designs can preserve large tracts of natural areas (forests, wetlands, etc.) that can be used for wildlife habitat or for passive recreational use.

LID practices should be implemented in those parts of the Basin that are zoned for higher density future land uses, such as the Rural Activity Center in the vicinity of Meridian and 224th Street East and in the general vicinity of Graham. LID Best Management Practices (BMPs) in these high-density areas could mitigate for increased stormwater runoff that will be generated by future development, prevent localized flooding, reduce stormwater runoff volumes, and reduce water quality impacts. LID practices should be implemented as included in the County's stormwater manual and development regulations, and the new Washington Department of Ecology *Stormwater Management Manual for Western Washington*.

Another benefit of LID is that it can result in more attractive, greener development, which can increase property values. Finally, LID can provide tools for cost-effective retrofitting of stormwater infrastructure, which has proven to be an expensive concern to many communities in the past.

Conclusion: The County should develop and implement a pilot program to determine the effectiveness of Low Impact Development techniques within the Muck Creek Basin.

9.2.2 Fish Habitat Protection

Riparian buffers afford habitat and protect water quality. While a wider riparian buffer performs better, even a minimal undisturbed buffer strip provides much more protection than none at all. There are several programs to fund riparian zone protection. Funds are available through the Conservation Reserve Enhancement Program (CREP) of the Natural Resource Conservation Service (NRCS). Under this program, the landowner can be compensated for 150 percent of the income-generating potential of the riparian area set aside and paid out annually. This can be applied to livestock or crop production.

The Salmon Recovery Funding Board (SRFB) administers grants to provide funding of habitat protection and restoration projects and that have a certainty of success and produce benefits for fish. Local and state governments, private landowners, conservation districts, Native American tribes, non-profit organizations, and special purpose districts are eligible to receive funding through the SRFB. In April, 2002, $36.7 million in grants were approved in Washington State to fund habitat protection and restoration projects across the state. Combined with local matching funds, a total of $57.6 million was allocated for 128 individual projects. The SRFB accepts project lists from designated local Lead Entities (including Pierce County) established under the Salmon Recovery Act (RCW 77.85 or 2496). A panel of scientists review and rate the projects for benefit to salmon and certainty of project success. The Nisqually Indian Tribe is currently the Lead Entity for the SRFB process in the Nisqually River Basin. The SRFB seeks to fund projects that are both scientifically sound and locally supported. This can be a major source of funding for the stream habitat restoration projects carried out in the Basin.

Conclusion: The County should develop and implement a program(s) that will facilitate the protection of habitat areas.

9.2.3 Compliance Assurance

The protection of stream channels from encroachment can also be addressed by compliance with environmental regulations. The County has Development Regulations intended to protect critical habitat areas (Title 18E, Pierce County Code). As an NPDES municipal stormwater permit holder, the County is required to have a program of legal authority, inspections and

others for water quality protection. Local critical areas rules, NPDES requirements, and other federal and state rules define certain uses and activities that are prohibited within surface waters, stream, and or their buffers. Use and activity regulations prohibit new development and existing landowners from undertaking new activities that could degrade water quality, increase erosion, cause riparian damage, or lead to flooding. Some examples of prohibited activities include: destroying or altering vegetation through clearing, harvesting, cutting, intentional burning, shading, or planting; application of pesticides, fertilizers, and/or other chemicals; constructing, reconstructing, demolishing, or altering the size of any structure; or activities which alter water temperature.

Where livestock or cropping land uses currently occur adjacent to streams, landowners should be encouraged to establish riparian buffers and agricultural BMP's through ongoing County programs, particularly the Conservation District.

Enforcement of development and environmental regulations would greatly reduce extensive stream bank and riparian damage throughout the Basin.

In those limited areas of the Creek (reaches of South Fork) that are subject to the Shoreline Management Use Regulations, new activities within 200 feet of the ordinary high water mark of the creek are subject to review and shoreline permits may be required. The permit review process affords an opportunity for working with the landowner toward mutual benefit.

Most of the development in the Basin preceded current Comprehensive Plan designations and Development Regulation provisions. However, new development must meet the current County stormwater management requirements, required as part of the County's NPDES permit, which require adequate water quality treatment and runoff control and include inspection and maintenance requirements. In addition, there are requirements for strict control of erosion and sedimentation control during construction activities.

An effective compliance assurance program includes tools such as outreach, education, technical assistance, inspections, and formal and informal enforcement. Current (February 2003) state, federal and local regulations exist that provide for water quality, habitat, critical areas and land use protection. A credible, effective program of consistent, fair and equitable compliance assurance actions would improve natural resource and surface water management within the Basin.

Conclusion: It is recommended that the County develop and implement programs that will ensure compliance with existing regulations, including public outreach and education.

9.2.4 Land Use Management

To ensure protection of Muck Creek and the natural resources within the Basin, development levels should be kept to those currently supported through existing plans and regulations. The existing rural land use designations that have been developed to implement Growth Management in Pierce County recognize that this area is outside the area where urban level densities can be readily sustained. The majority of the Basin is zoned for agricultural or rural residential development at densities of one dwelling unit per 5 or 10 acres, depending on the specific zoning designation. (These are the "base" densities, per Section 18A.35, Pierce County Development Regulations. Increases to up to two units per 5 acres or two and one-half units per 10 acres can be permitted, subject to some restrictions on land usage). Future land uses at these densities will result in relatively low levels of impervious surface development, generally less than 8 percent. Basins with impervious areas of this magnitude generally do not experience serious stream erosion or other negative hydrologic impacts. It is not expected that future development in the Basin will contribute significant amounts of new runoff to the creek, therefore, these densities are appropriate for the long-term development of the Muck Creek Basin. Combining the appropriate development density with the compliance assurance program should result in enhanced protection of Muck Creek resources.

Future densities in the Graham area of the Basin are zoned for Rural Activity Center (commercial) along Meridian and up to two homes per five acres for most of the remaining area. Surface runoff in this area does not reach Muck Creek, but increased stormwater resulting from these densities can pose local drainage problems. Low Impact Development techniques and BMP's, as discussed above, should be implemented in this area to encourage on-site infiltration and prevent localized flooding.

The amount of additional water use needed to support future growth in the Basin is a relatively minor fraction of the potentially available within the Basin. Potential impacts related to increased water use are not likely to adversely affect water resources within the Basin (Section 7.1).

Approximately one-quarter of the Muck Creek Basin lies within Fort Lewis and includes nearly all of the lower portions of the stream system. Activities within Fort Lewis over the years have been a source of concern for area residents who are concerned about the Creek. Future development and training activities at the Fort have the potential for substantial impact upon the stream. Stream crossings by tanks have been blamed for loss of disruption of stream flows and other impacts. The Army has committed to continue using the existing hardened fords for stream crossings to impacts. At this time, no development is scheduled for the eastern portion of the base, within the Muck Creek Basin. As a result, future operations on the Fort Lewis portion of the Basin are expected to have somewhat lower impact in the Basin than current operations (CH2M Hill, 2001).

Development at the rural densities designated by the existing Comprehensive Plan is appropriate for minimizing storm drainage issues and impacts to the streams in the Basin.

Conclusion: The County should develop and implement programs that involve cooperative efforts between agencies, and that ensure compliance with applicable land use, environmental and development regulations.

9.2.5 Critical Areas Conservation

Potential critical area acquisition must take into account that major portions of Muck Creek typically go dry nearly every year, thereby isolating upstream areas. These include sections upstream and downstream of Roy and several miles on both sides of Highway 507 on Fort Lewis.

On Fort Lewis, Exeter Springs and Johnson Marsh are very important in that they provide stream flow essential for sustaining the chum salmon runs in Muck Creek. Lying within the Fort, these are protected from potential development.

A large percentage of the watershed upstream of Fort Lewis was examined during stream surveys. Very little high quality stream habitat was encountered which would merit possible acquisition and permanent protection. The best habitat found was on the South Fork, two miles upstream of 8th Avenue East. This portion of the South Fork lies upstream of the dry stretch of stream located on Fort Lewis. Even though this reach is perennial, the seasonal isolation from perennial waters downstream greatly limits its potential habitat value for anadromous fish.

Patterson Springs is a critical area that is the major source of flow to the upper North Fork and is essential for assuring the perennial flow of this important part of the Muck Creek stream system. Associated with this spring is the large wetland which forms the upper end of the North Fork. This wetland lies north of 252nd Street E, parallel to and about one-quarter mile east of 70th Avenue East. The Cascade Land Conservancy has acquired nearly 100 acres lying south of 252nd Street SE to establish the Morse Wildlife Preserve. The wetland area north of 252nd Street SE should also be protected. Although portions of this wetland were once farmed and are in a degraded condition, it does serve an important function in helping to maintain perennial flow to the North Fork. It is recommended that this area be left in an undeveloped state and considered for permanent protection.

There are non-profit organizations that operate within Muck Creek Basin for the conservation of critical lands that have goals compatible with those of the County. For example, the Cascade Land Conservancy recently acquired a 45-acre property adjacent to the 53-acre Morse Wildlife Preserve in Graham. This property includes a portion of Muck Creek and a high-quality forested wetland. The Pierce County Conservation Futures Program provides funding to purchase environmentally important open space areas such as the upper portion of the North Fork.

Conclusion: The County should develop and implement programs to acquire and enhance habitat areas.

9.2.6 Public Education and Involvement

Individual components and recommendations of this Basin Plan should be incorporated into a comprehensive public education program to inform Basin residents about conditions of the creek and its watershed, any potential capital improvement projects to be completed in the Basin, and individual actions that can contribute to restoration and protection of Muck Creek's natural resources.

An ongoing watershed education program of the County would help to educate watershed citizens about the consequences of their actions and to encourage them to change their habits to protect the creek and its watershed. Educational activities can be developed for schools in the Basin and for the general public. Specific activities will be targeted to both young and adult

audiences, and will be related to existing community programs wherever possible. A focal point in the Basin for citizen involvement in stream and riparian restoration projects is needed and can encourage media attention to watershed activities and events. Organized guided tours of the Muck Creek Basin will help residents to better appreciate the creek and its natural resources. Interpretive programs as part of the tours can explain the natural processes of the Basin and residents' responsibility to help protect the creek.

There are a number of measures that can be undertaken by landowners to mitigate potential impacts from use activities. Some protective measures include the establishment of buffers, fencing livestock and farm animals from wetlands, streams, and their buffers, and building setbacks from buffers. Section 18E.60.050C currently (February, 2003) establishes a stream buffer width of 35 feet for Muck Creek and its tributaries to protect the creek which apples to new uses. During field evaluations, impacts from livestock were observed in many areas of the creek. For existing uses, this requirement could be voluntarily moderated with the allowance for limited stream contact for stock watering purposes. For instance, cattle could be allowed contact with 30 linear feet of stream per property or 30 feet per quarter mile of stream through larger properties. Although such restriction would require considerable fencing or other isolation measures, and may be a stumbling block for compliance by affected landowners, it may be possible to work with agencies such as the Pierce Conservation District.

A comprehensive public education program can be effective in involving Basin residents in the Watershed and in capital improvement projects or individual actions that can contribute to restoration and protection of Muck Creek's natural resources. This public education program would include specific components and recommendations included in this Basin Plan. Examples of public education activities and tools include:

- Public workshops to introduce the Basin Plan recommendations to Basin residents.
- A Muck Creek Basin newsletter focusing on water quality, fish, habitat, and other watershed issues, community activities, and projects throughout the Basin.
- Creation of a Basin management position to coordinate watershed education activities and citizen involvement in stream and riparian restoration projects, and bring media attention to watershed activities.
- Interpretive programs and Basin tours to explain the natural processes of the Basin and residents' responsibility to help protect the creek.
- Brochures and fact sheets on the specific elements of the Basin Plan.
- Posters, signage and displays at community events on water quality, flood control, and fish habitat issues.
- Citizen involvement projects such as trash removal near the creek, storm drain stenciling, and water monitoring activities.

Stream and riparian restoration projects should be organized to maximize the opportunity for Basin residents and other citizens to participate. In addition to making more effective use of limited funds, citizen participation in restoration projects is one of the most effective methods for educating residents on important Basin issues. Joint cooperation and funding of existing groups' publication efforts (Nisqually Tribe, Muck Creek Council, Conservation District) is another effective way of making effective use of funds and efforts devoted to public education.

Conclusion: Programs should be developed and implemented to provide public outreach and educational opportunities within the Basin and to maximize public participation.

9.2.7 Flood Hazard Management

One purpose of the Basin Plan is to provide information and direction to the County in mitigating flood hazards within the Muck Creek Basin. Pierce County participates in the National Flood Insurance Program administered by the Federal Emergency Management Agency (FEMA). FEMA also offers communities the opportunity through the Community Rating System (CRS) for additional benefits. This program makes subsidized flood insurance available for citizens where their communities take actions to reduce flood hazards. The community rating affects flood insurance rates within the County. Pierce County has one of the lowest cost flood insurance rates available, having been the first county in the nation to achieve a "Class 5" rating", through implementation of programs that reduced flood risks. This Basin Plan includes all the necessary program elements for the County to achieve a "Class 4" or better rating. On a Countywide basis, these measures also include the adoption of more restrictive flood hazard regulations and improved mapping of flood hazard areas.

Risk Assessment

As mentioned previously, flooding problems have not been a major issue within the Muck Creek Basin. According to the Pierce County Geographic Information System, and current Pierce County Flood Hazard area maps of the Basin of the nearly 43,000 acres within Pierce County's jurisdictional area of Muck Creek Basin, only 1,689 acres (approximately 4%) are located within an "A" Flood Zone, the area that statistically is anticipated to be flooded once every 100 years. Maps indicate that 2,177 acres (approximately 5%) are located within the "B" Flood Zone, the area that statistically is flooded once every 500 years. (See Figure 9-1.)

Throughout the Basin, only 47 buildings are estimated to be located within the "A" Zone, and 171 buildings are estimated to be within the "B" Zone. The number of structures was determined by selecting those individual parcels within unincorporated Pierce County that were shown as having a flood zone that extended landward from the potential flood source to at least 50% of the depth of the parcel.

The Muck Creek Basin is within the area of Pierce County that is designated as "Rural" under the Comprehensive Plan, the document that guides land use and development activity. The zoning within the Basin is mostly Rural 5 and Rural 10 (See Chapter 5). The base density for new development in these classifications would be 1 unit per 5 acres, and 1 unit per 10 acres, respectively. At these densities, and with the enforcement of County Critical Areas Development Regulations and Flood Hazard Regulations, it is very improbable that major new development could aggravate existing flooding problems.

The Plan supports programmatic measures to develop and implement projects that will serve to reduce flood hazard impacts. These include, but are not limited to: PG00-02, Adopt Updated Stormwater Management Standards; PG00-04, Develop and Implement a Land Acquisition Program for Riparian and Wetland Habitat Protection and Flood Hazard Reduction; PG00-05, Develop and Implement a Program to Enhance Degraded Riparian Habitat and Water Quality and to Provide Flood Attenuation; PG00-06, Develop and Implement an Education, Outreach and Technical Assistance Program and PG00-07, Develop and Implement a Surface Water Management Monitoring Program.

Studies that would provide information to reduce flood hazard impacts are also recommended in the Plan. ST12-02, Identification of Flooded Depression Areas and ST12-03, Detailed Flood Study along South Fork Upstream of Mountain Highway will address these issues. In addition, several CIP's have been proposed to alleviate localized flooding problems through stormwater facility improvements. Other CIP projects involve the acquisition of areas. Many of the problems were identified as the result of information provided by area citizens (See Chapter 3, Stakeholder Involvement, and Chapter 6, Flooding Problems.)

The Plan is intended to identify projects and processes that will reduce flood hazards, and contains a wide range of approaches to meet that goal. Those projects or processes that do not support that goal were not included in the Plan. Examples of proposals that were rejected outright include:

- Construction of a stormwater facility that is not sized sufficiently to accommodate flood events;
- Recommend actions to increase development densities major in-stream flow augmentation; and
- Extensive channel morphology modifications.

Major Tributaries

Flood problems along the main tributaries within the Muck Creek Basin are comparatively few. Some flooding in the City of Roy has occurred in the past when the Lacamas Creek overflowed its banks due to thick channel vegetation (Section 5.3) and culvert blockages under SR 507. Periodic channel clearing has been carried out in the past to address this problem. Riparian revegetation and tree planting, contained in CIP recommendations, are long-term measures to permanently shade out the offending reed canary grass growths in the stream channel to ease this problem. High flows in the South Fork, just upstream of its crossing of SR 7 (Mountain Highway), can threaten several homes and block local access roads. To address this problem, it is recommended that a detailed hydraulic study (supported by 2-foot topography) be carried out of a one-mile length of stream upstream of the Mountain Highway. Finally, there are several undersized road culverts recommended where high flows can overtop the road. CIP improvements address these flooding problems. Flood studies and improved mapping of flood zones would also help alleviate such problems.

Ponded Water

The most common flooding problems in the Basin result from ponded water conditions which can occur after heavy periods of rain. The topography across much of the Basin is flat to gently rolling and frequently forms shallow depressions. As a result, many areas within the Basin do not have a surface connection to a stream. Instead, rainfall runoff frequently flows to such depressions where the water will pond while it slowly infiltrates. Although ponded water locations and depths are not well-documented in the Basin, the maximum ponded depths are typically three feet or less. Roads, homes or other property located within these depressions can be impacted until the ponded water subsides. Piping this water to some other location is rarely a practical option since it typically would involve relatively long pipelines. The low density of housing and other structures in the Basin generally precludes regional drainage measures covering large areas. For new development and associated roads, the most effective measure

is avoidance of depressions. If a road crosses a depression, it should be elevated above the potential ponding level.

Homes with an existing water ponding problem have limited options. The home may be physically raised in place or moved. Both are expensive approaches for a home-owner. In one observed case, the owner dealt with the problem by excavating a depression and directed runoff from the area around his home to this pond. However, if the seasonal water table rises near the ground surface, this approach may not provide much relief.

The available topographic mapping for the Muck Creek Basin is laid out in 5-foot contour intervals. This is not detailed enough to reliably identify local depressions that might pond runoff. It is recommended that 2-foot topography be developed for the Basin. Internally-draining depressions could then be mapped using the County's GIS System. It is recognized that not all of these depressions would necessarily pond and cause potential flood problems, but this would provide valuable information for potential development and for the routing of new roads.

Proposals for major new development in the County require, among other things, that an assessment be made of the drainage conditions downstream from the development. For the Muck Creek Basin, this downstream assessment should explicitly review whether the project will be impacted by, or drain to, a depression. If this is the case, the hydrologic analysis provided by the project proponent should demonstrate that the project will not be impacted by onsite ponding nor contribute substantially to an offsite ponding problem. In addition to site-specific ponding information provided by the County, information regarding past ponding incidents should be sought from the local residents. Access roads routed through a depression may be mitigated by providing a second access road through an area which is not subject to potential flooding.

Graham Area

Runoff from the northeast portion of the Basin does not directly flow to any tributary (Section 4.4). Instead, it infiltrates locally or collects in several depressions and seeps into the ground. Some of this groundwater reaches Patterson Springs and the upper North Fork of Muck Creek, and is critical in maintaining the year-round flow of this stream. However, some of this groundwater may travel northwest and enter the Clover Creek Basin. Although several regional groundwater studies have been conducted, none have specifically addressed groundwater flow in the Graham area. A large portion of the Graham area drains to a depression located west of the shopping center at the intersection of Meridian and 224th Street. A large regional infiltration basin is proposed for this location as part of the CIP List in this Chapter. Additional information is needed with respect to regional groundwater movement in the Graham area. This study may include further recommendations for stormwater management in the area.

Conclusion: The County should develop and implement programs and projects that reduce flood hazards. These programs would include adoption of more stringent Flood Hazard Area Regulations, public education and outreach programs, compliance assurance programs, conducting studies that provide additional information about potential flood hazard areas, and acquisition of lands that are within riparian and wetland areas. Capital Improvement Projects that will reduce flood hazards should be constructed.

9.2.8 Water Quality

NPDES Stormwater Management, Countywide

The Washington Department of Ecology (WDOE) issued its updated the Stormwater Management Manual for Western Washington in 2001. This updates the 1992 Puget Sound Stormwater Management Manual. The requirements for detention and for water quality treatment from higher-density land uses have been strengthened. The list of BMP's has been broadened. The manual is aimed primarily at urbanizing areas and commercial and industrial developments. It is thus most applicable to the Roy and Graham areas of the Basin. Individual jurisdictions will be required to adopt stormwater regulations which are functionally equivalent to those of the new Ecology Manual within the next several years. The County's NPDES permit requires implementation of equivalent standards contained in the manual. The County's current Stormwater Management and Site Development Manual, Title 17A, is the technical equivalent of the 1992 Ecology Manual.

Conclusion: The County should adopt updated stormwater management standards that are consistent with the most recent WDOE stormwater manual.

Basin-Specific Water Quality Management

The two water quality parameters which most consistently exceed state standards are water temperature and bacteria (coliforms). (See Chapter 7.) In addition, the settlement of fine sediment in the channel bottom is a common cause of degradation of fish habitat. The measures needed to bring improvements to these parameters are quite similar to those identified for stream and riparian habitat improvement. Restriction of livestock access to streams in the Basin will greatly reduce the amount of stream bank and channel instability caused by this practice. This, in turn, will reduce stream sedimentation and allow the re-establishment of higher quality gravel substrate in the stream bottoms. Bacterial contamination of the streams due to animal sources will also decline.

Riparian revegetation is a key measure which can reduce the incidence of higher stream temperatures. Trees, particularly conifers, are needed along many sections of the streams to provide shade and moderate temperature increases during warm, sunny days. However, there are several factors in the Basin that may limit the effectiveness of a tree canopy in reducing stream temperature rises. Large portions of the central basin lie within prairie areas. Riparian trees are typically limited to the immediate area of the stream, itself. Conifers are not a natural component of the streamside vegetation. Oregon ash and cottonwood may be more appropriate riparian trees in this setting. Riparian restoration in the prairie areas should be closely coordinated with Fort Lewis, where the majority of this ecosystem is located within the Basin. Another factor influencing stream temperature through the Roy area is the upstream lakes: Muck and Chambers lakes. The open water of these shallow lakes cannot be shaded and is subject to direct heating by sunlight. Inflow from Lacamas Creek, at Roy, probably moderates this temperature increase somewhat. Warm water release from these lakes typically occurs only during the early summer, as the main stem usually goes dry after mid-summer.

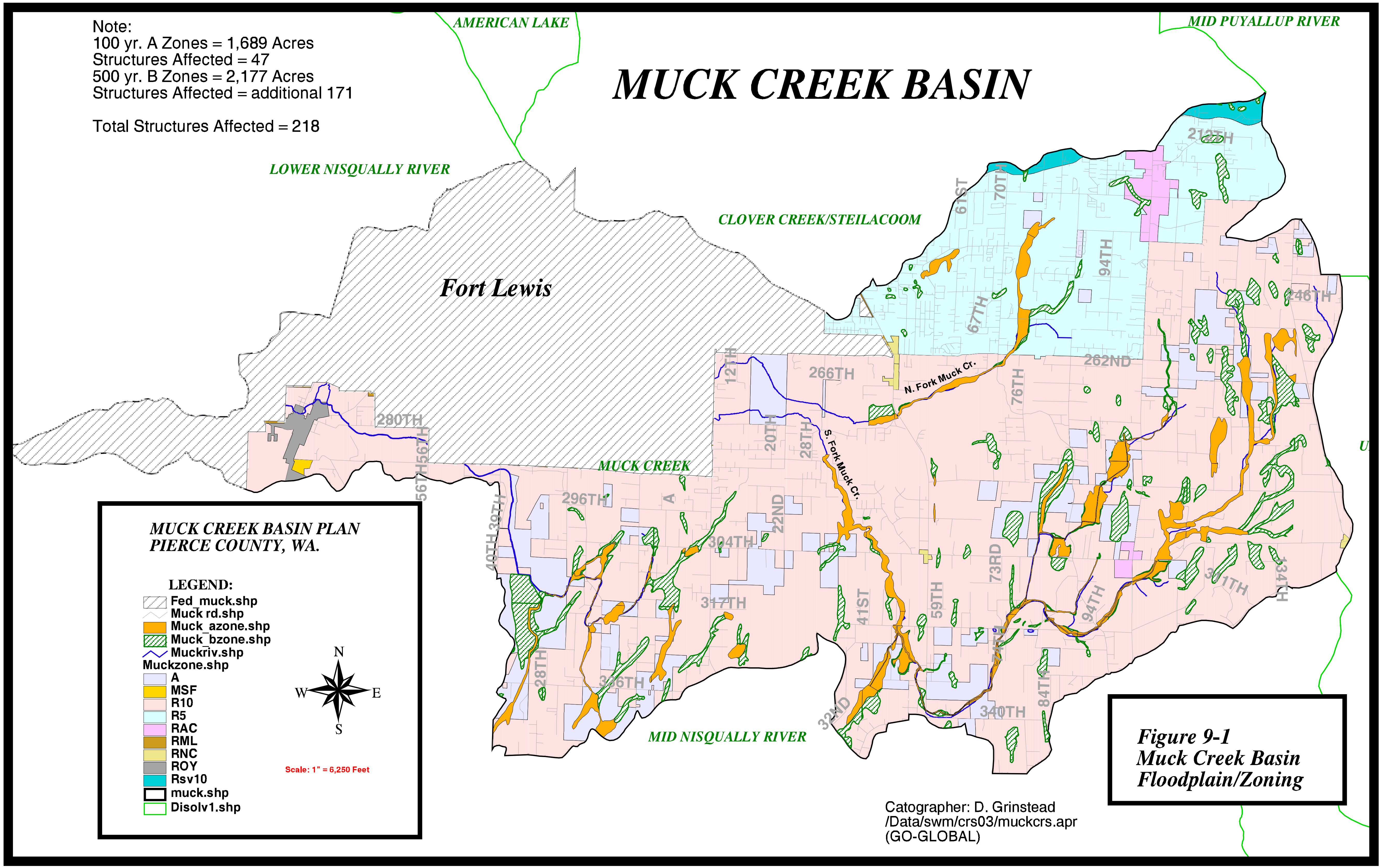
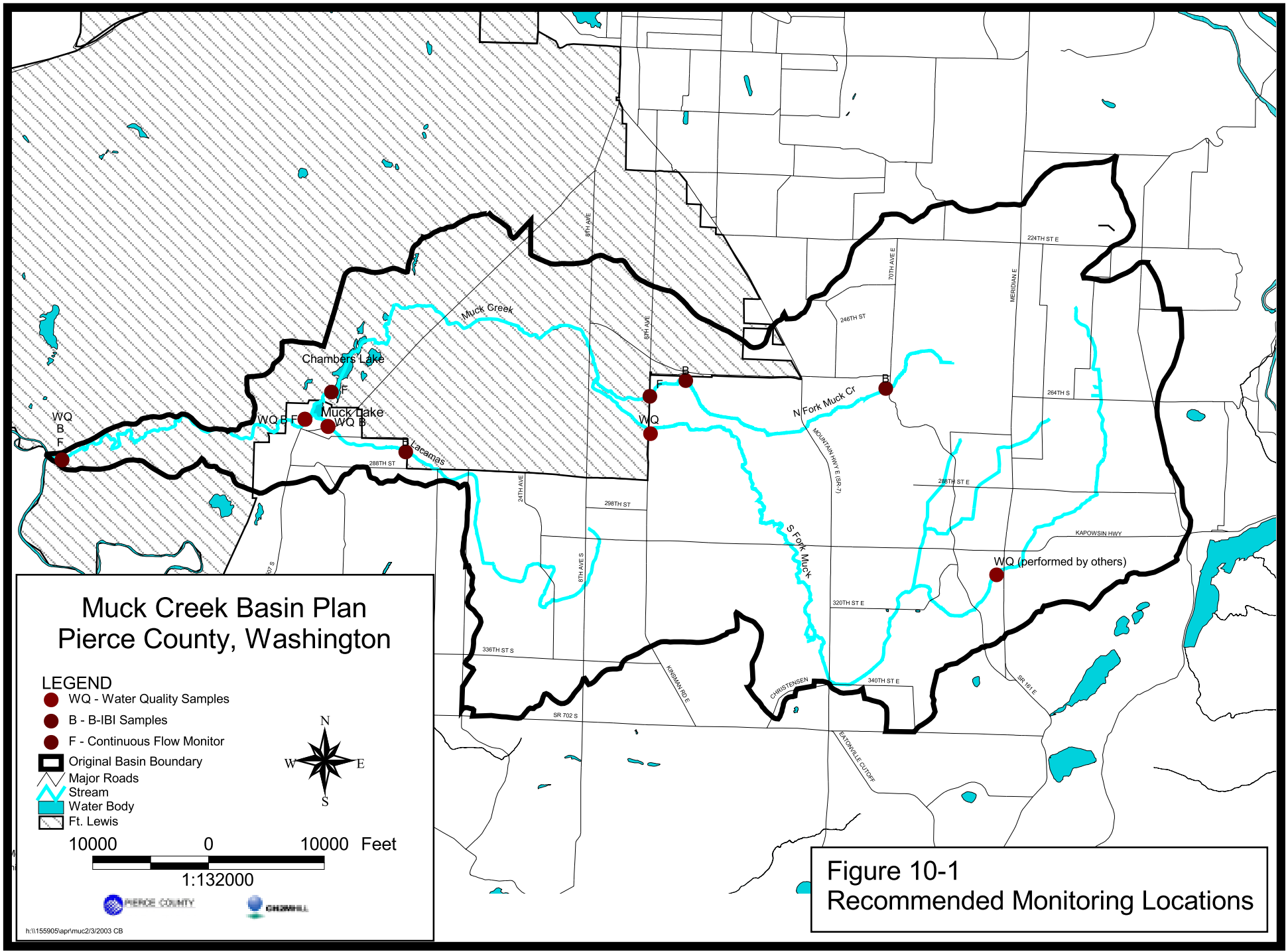


Figure 9-1
Muck Creek Basin
Floodplain/Zoning


Muck Creek Basin Plan
Pierce County, Washington
LEGEND
WQ - Water Quality Samples
B - B-IBI Samples
F - Continuous Flow Monitor
Original Basin Boundary
Major Roads
Stream
Water Body
Ft. Lewis
N
W
E
S
10000 0 10000 Feet
1:132000
PIERCE COUNTY
CH2MHILL
h:\\155905\apr\muc2/3/2003 CB
Muck Creek
Chambers Lake
Muck Lake
WQ B F
WQ B
WQ
B
F
Lacamas
N Fork Muck Cr
S Fork Muck
WQ (performed by others)
288TH ST
298TH ST
320TH ST E
336TH ST S
340TH ST E
SR 702 S
224TH ST E
246TH ST
264TH S
288TH ST E
KAPOWSIN HWY
MOUNTAIN HWY E (SR-7)
MERIDIAN E
70TH AVE E
24TH AVE
8TH AVE S
KINSMAN RD E
CHRISTENSEN
SR 161 E
EATONVILLE CUTOFF
Figure 10-1
Recommended Monitoring Locations

An additional benefit from the establishment and revegetation of riparian buffers is the water quality improvement that is expected to occur. Runoff from adjacent activities such as residences, animal grazing, crops, barnyards and animal confinement areas is slowed and filtered as it passes through the buffer. This allows for more effective removal of sediment, organic matter and nutrients than is the case where such activities occur immediately adjacent to the stream. Thus, an effective riparian restoration program in the Basin will have benefits for both water quality and stream habitat.

Long-term data on the Muck Creek system is needed to document flow and water quality trends. Long-term data is also essential to document improvements which may occur as a result of implementing the programmatic and other recommendations and the CIP's listed. Monitoring can be costly and an attempt has been made to strike a balance in obtaining the proper amount of data to adequately characterize Basin trends.

Water quality monitoring points on each of the major tributaries and at two key locations on the main stem of Muck Creek (Figure 9-2) would aid in documenting ambient conditions. Monthly samples should be collected and analyzed for a similar suite of parameters as was monitored in the Fort Lewis and the Nisqually Tribe monitoring programs during the 1990s (Table 9.3). This assures continuity of the water quality data and aids in trend analysis. As part of the monitoring program, water samples could be collected and analyzed for herbicides and pesticides commonly used in the Basin to determine if this might pose a water quality problem. The Agricultural Extension Service can be consulted for candidate chemical parameters.

TABLE 9-3
Water Quality Monitoring Parameters

Temperature
Dissolved Oxygen
pH
Suspended Solids
Turbidity
Total Phosphorus
Ortho Phosphate
Nitrate
Ammonia
Fecal Coliform

The two recording flow meters installed during the current study should be retained. The North Fork meter records the only perennial stream within the upper basin. The Roy Gauge, on the main stem of Muck Creek, adds to the continuous flow record dating from the 1950s to the 1970s. In addition, this is a good location for recording those periods when stream flow ceases during the dry season. Two additional flow monitoring locations are recommended, both on Fort Lewis. A flow recorder should be installed at or just downstream of the Chambers Lake outlet. This would be very useful in achieving proper gate adjustment of the outlet gate, both for fish passage and for minimizing downstream flow fluctuations. A continuous recorder should also be installed near the mouth of the creek where it discharges to the Nisqually River. The lower two to four miles of the stream are perennial and offer the most consistent spawning habitat within the Basin. Long-term data on stream outflow would also allow for a better estimate of the proportion of runoff that leaves the Basin via the regional groundwater aquifer.

B-IBI samples were collected during 2000 and 2001. They should continue to be taken annually during the late summer. This data provides a good indicator of stream health and can effectively document trends in water quality.

Every three to five years a report should be developed which summarizes the monitoring data collected in the Muck Creek Basin. This report should document discuss CIP's that have been constructed during the period and review any flow and water quality trends, particularly as they are related to constructed CIP's and/or programmatic measures in the Basin. It would also document flooding problems which occurred during this period. The report should include a summary of ongoing County drainage maintenance and flood control activities in the Basin. This report would also be an opportunity to add additional programmatic measures or CIP's and to modify priorities, as needed, to address emerging problems or changing conditions. Thus the report would document the adaptive management process used to assure that the Basin Plan remains current and continues to effectively address flooding, water quality and stream habitat problems.

Conclusion: The County should develop and implement programs that will protect and preserve water quality within habitat areas. One means to accomplish this is to establish and maintain buffers along habitat areas, education and outreach programs would also be valuable. The County should establish an on-going water quality monitoring plan with regular reports, and enough information for adaptive management opportunities.

9.2.9 Reed Canary Grass Management

There are numerous large-scale opportunities for reed canary grass eradication within the Muck Creek Basin. The largest contiguous stand is on Lacamas in the reach between 288th Street S and a large dairy located more than a mile upstream. The reach is about two miles long. The growth is thick enough to block fish movement and passage. The lack of shade for such a long length probably increases water temperature significantly. Another, more important reach is at the mouth of Lacamas Creek in Roy, near the vicinity of Muck Lake. The position of this monotypic stand of reed canary grass low in the Lacamas system makes it especially important. There are a number of fairly long reaches of reed canary grass on the South Fork in the vicinity 320th Street E. and SR 7. There are numerous smaller stands of reed canary grass throughout the upper basin that should be controlled. Many of these are on smaller properties. Several landowners indicated that they would be very pleased if the County would help them deal with this problem as they have been battling reed canary grass on their own unsuccessfully for flood control purposes.

Conclusion: The County should develop and implement a program to reduce impacts in the aquatic environment caused by invasive plant species.

9.2.10 Riparian Corridor Management

Perhaps the most important and practical single measure that can be implemented to enhance salmon habitat in the long-term, is riparian tree planting. With high temperatures, lack of LWD, and extensive reed canary grass problems, riparian planting programs should play a major role in the Muck Creek Basin. While a number of groups are already conducting such programs in the Basin, much more is needed. The most effective way to remove reed canary grass is by shading it into submission. Conifers are considered by some to be best for this, as hardwoods

allow early spring and late fall growth to occur unhindered. But willows can crowd out reed canary grass with their root mass if allowed to become established through a program of proper maintenance during the interim period. Strategic tree planting can be used to ultimately reshape and widen floodplains. Trees, both conifer and hardwoods, will ultimately contribute LWD to the channel, but this is a long-term process. The benefits of shade and reed canary grass control will come much sooner.

In the areas which have historically been prairie, there is the potential to enhance the natural oak habitat which has declined in the Basin (see Section 4.7). The distinguishing tree is the Oregon white oak. Hanna and Dunn (1996) identify three distinct types of oak habitats: oak savannas and open woodlands, riparian oak woodlands and wetland oaks. The latter two habitat types could be appropriate for prairie areas recommended for riparian restoration. Riparian oak woodlands most often appear as thin bands of vegetation which form between grasslands and a watercourse. The oaks typically are located upland from the more moisture-tolerant trees which typically border a stream. A revegetation plan for such areas should incorporate oaks and their associated understory where appropriate. The Nisqually Indian Tribe has prepared an analysis of riparian habitat on Fort Lewis that is a good resource for information about appropriate plant species. (Dorner, et. al., 2002).

Conclusion: The County should develop and implement a program(s) for restoration and enhancement of habitat areas within the Basin. The program should include opportunities for coordination with other stakeholders.

9.2.11 Instream Habitat Improvement

There are several fish habitat elements that are in need of improvement in the Muck Creek Basin. The two most important instream elements are channel morphology and LWD. As mentioned previously, much of the stream channel appears to have been intentionally made narrow at some time in the distant past, and there is far too little LWD present. Unfortunately, extensive channel morphology modifications would be entirely too expensive to be practical. The potential habitat improvements are also constrained by the intermittent nature of Muck Creek downstream of many potential channel restoration sites which are largely unavailable to anadromous fish. Placement of instream LWD would create much needed pool habitat, but due to the narrow stream conditions may create local flooding problems if this potential problem is not considered carefully. One of the reasons why there is so little instream LWD is because it has historically been removed from the channel to prevent flooding. Because of its position relatively low in the watershed and its perennial nature, Lacamas Creek is a likely candidate for LWD placement. Instream habitat restoration will be most practical when it is implemented along with other measures such as riparian enhancement in a comprehensive restoration project.

Even established older stands of alder do not provide the same quality of salmon habitat function as do conifers. Conifer LWD is generally larger and lasts much longer in water than does hardwood LWD. Selection of conifer species must be based on site conditions and geographic setting. Conifers may not be appropriate in the prairie areas of the Basin. The typically wet conditions next to streams is generally best suited for cedars, hemlock, and Sitka spruce. Cedars provide the highest quality LWD but are also the slowest growing conifers of the group mentioned. Conifers can be interplanted in alder and maple stands. Cedars are especially shade tolerant. One potential limitation to the ultimate success of such a program is that agreements should be made with landowners or regulations put in place to preclude the ability of landowners to cut down these plantings at a later date when they become

commercially harvestable in 40+ years. Species selection should take the local ecosystem and historic character of the area into account.

Conclusion: The County should develop and implement a program(s) for restoration and enhancement of habitat areas within the Basin. The program should include opportunities for coordination with other stakeholders.

9.2.12 Livestock/Riparian Interactions

Livestock enclosures allow riparian buffers to become established and also limit the spatial extent to which animals are allowed contact with stream channels. If watering access is limited to sections of stream that are narrow, perhaps 30 feet, and the banks are graded back and hardened, these sacrificial areas can protect hundreds of yard of habitat. The use of nose pumps or electric pumps can completely eliminate the need for livestock to come in direct contact with the stream.

Conclusion: The County should develop and implement a program for education and outreach so that homeowners can be educated about the value of restricting livestock access and to provide information about available assistance.

9.2.13 Filling Information Gaps

During development of this Basin Plan, it became evident that there was a need for additional data to effectively address a number of issues. Recommendations for additional studies are given below.

An aerial photographic survey immediately following a major storm event would provide valuable information about flood problems across the Basin. Many of the flooding investigations carried out during the course of this Basin study stemmed from limited County records of ponding and drainage problems following a major storm which occurred in 1996. The County personnel recorded hundreds of problems throughout the County during a several-day period. Many of these records were too sketchy to evaluate. An aerial photographic record of Muck Creek and other basins in the County would be a cost-effective way to more accurately document these types of flooding problems.

Additional detailed topographic mapping at the 2-foot contour interval would be useful for the Muck Creek Basin. This mapping could be used to better define local topographic depressions that may be subject to periodic flooding. Such information is important reviewing new development proposals in the Basin and would also be very useful in evaluating existing flooding problems. In conjunction with this, flood hazard mapping should be conducted along the upper portions of Lacamas Creek and the South Fork of Muck Creek, both of which currently lack this information.

A detailed flood study (with supporting 2-foot topography) should be conducted along the South Fork, upstream of Mountain Highway (SR 7). Floods through this area periodically threaten homes.

Information presented in Section 4.4 indicates that groundwater recharge which occurs in the Graham area may be contributing to seasonally high water tables and flooding in the

Clover/Chambers Basin, which is located immediately north of the Muck Creek Basin. It is recommended that a study of groundwater levels and movement be conducted in this area to determine the degree (if any) to which the northeastern portion of the Muck Creek Basin contributes to flooding problems in the adjacent basin. Virtually all of the stormwater runoff in this portion of the Basin infiltrates to the groundwater. To the degree that the groundwater from this area moves into the Clover/Chambers Basin, an adjustment in the Basin boundary should be evaluated.

Conclusion: The County should conduct Basin specific studies that provide information required to reduce flood hazards.

9.2.14 Stakeholder Involvement

Broad, multi-stakeholder groups such as the Muck Creek Council can be instrumental in implementation of the Basin Plan. Representatives of environmental interest groups, tribes, and individual citizens provide valuable review and support of specific activities and ongoing progress of the Basin Plan recommendations. These groups can also be instrumental in carrying out an effective public education campaign. The Muck Creek Council should continue to serve as a forum on Basin issues.

Businesses in the Basin should be contacted to involve them in implementation of the Basin Plan recommendations. The private sector will need to comply with regulations to protect the water resources and habitat of the Muck Creek Basin. Additionally, businesses may be partners in developing creek and natural resource protection strategies, and may also offer funding assistance for individual and/or ongoing watershed activities.

Farmers and other large landowners with extensive property along Muck Creek and its tributaries can play a critical role in addressing the temperature and sedimentation problems. The establishment and revegetation of riparian buffers is the single most important measure for improving water quality within the Basin. The Pierce County Conservation District can be effective in this regard especially in its efforts to promote agricultural BMP's and farm water quality plans.

Actions carried out on Fort Lewis are critical in maintaining and improving stream habitat and water quality. Activities the Fort could consider include:

- Implementation of the planned on-Fort stream and wetland restoration projects
- Completion of the on-Fort field assessment of Muck Creek
- Manage flow releases from Chambers lake in a manner that reduces downstream flow fluctuations
- Assistance in the long-term monitoring program (see Section 9.5)

Conclusion: The County should develop and implement a program that provides for outreach to, and coordination with, other agencies and jurisdictions within the Basin and that facilitates stakeholder involvement.

9.3 Specific Recommendations for the Muck Creek Basin

The following are specific recommendations to address flooding, water quality, and habitat problems within the Muck Creek Basin.

Capital Improvement Projects

Flooding and Drainage Problems

The locations of these projects are shown on Figure 9-3 of the Muck Creek Basin Plan.

CIP12NF-CUL01: "216th St. E Conveyance Improvements"
(216th St. E and 118th Ave. E)
Cost: $4000 Score: 45

Problem: Runoff from large area consisting of public streets and adjacent property drains to a ditch northwest of the 216th St and 188th Ave E intersection. The ditch crosses private property and is overgrown with grass vegetation. This ditch can back water up onto 216th St E and can cause intersection flooding.

Solution: Perform maintenance of the ditch north of 216th St E for a distance of 300 feet. Since this ditch lies within private property, an easement covering about 0.15 acres will be needed. An 80-foot culvert needs to be constructed from the existing drywell, west across 118th Ave to an existing road ditch.

CIP12NF-RD01: "238th St. E Conveyance Improvements"
(238th St. E. and 103rd Ave. E)
Cost: $2000 Score: 45

Problem: Water from 238th St E enters a private property and then flows down an embankment onto an adjacent driveway.

Solution: Construct a 100-foot curb extending from the crest of 238th St E to an existing road curb to prevent road runoff from leaving the road and entering private property.

CIP12NF-CULO2: "70th Ave. E Culvert Improvements"
(242nd St. E and 70th Ave. E)
Cost: $39,000 Score: 100

Problem: Flooding occurs along 70th Ave E. Water flows across a low spot along the road about 500 ft north of 242nd St E and floods private property. No culvert exists to drain the east roadside ditch to the lower west side at the road sag. A house on the property west of the road lies adjacent to a possible wetland.

Solution: Construct a 50-foot culvert under 70th Ave E at the low point to convey water to the west side of the street. A detailed site survey and hydrologic/hydraulic investigation should be

carried out to delineate the wetland on the west side of the street, identify property lines, topography and soil properties to determine if an infiltration pond or some other means of stormwater management is necessary to prevent/eliminate flooding of the nearby house.

CIP12NF-INF01: "242nd St. E Infiltration Pond"
(242nd St. E. and 49th Ave E)
Cost: $136,000 Score: 85

Problem: A private road 242nd St E floods about 100' west of 49th Ave E during large storm events. Some private property floods as well and there is no outlet for accumulated runoff. The ponded water can block the sole access available to a number of homes in the area.

Solution: A 7.5 acre-ft infiltration pond with a depth of 6 ft should be constructed. The pond would be located a short distance north and west of the existing low point in the gravel road. Five hundred feet of ditch would be installed along the road to convey runoff to the facility. Acquisition of 1.5 acres of land would be required.

CIP12NF-CUL03: "252nd St. E Conveyance Improvements"
(252nd St. E and 75th Ave. E)
Cost: $179,000 Score: 155

Problem: 252nd St E experiences frequent shallow flooding. This road crosses the upper portion of the North Fork. The two existing culverts underneath 252nd St E have inadequate capacity.

Solution: Install a 12' x 6' arch culvert to provide the needed capacity to eliminate road flooding. A detailed survey of several cross-sections downstream of the culverts would allow for a more refined hydraulic analysis and the possible reduction in the number of added culverts.

CIP12SF-CUL01: "288th St E Culvert Replacement I"
(288th St. E and 125th Ave. E)
Cost: $128,000 Score: 180

Problem: A tributary of the South Fork crosses 288th St E (7,200 feet east of Meridian E) in three 36" diameter concrete culverts. The culverts do not have sufficient capacity to pass the 100-year storm event and water from the creek overtops the road. In addition, the culverts are susceptible to debris blockage and frequently need to be maintained.

Solution: Replace the existing culverts with two 8' x 7' Concrete Box culverts 40 feet in length. The culverts are sized to allow for stream bed material in the bottom of the culvert.

CIP12SF-CUL02: "Orting-Kapowsin Highway Conveyance Improvements"
(288th St. E and Orting-Kapowsin Highway)
Cost: $10,000 Score: 85

Problem: Stormwater overtops 288th St E and floods the property owner on the southwest corner of the intersection of 288th St E and the Orting-Kapowsin Highway. In the winter, frozen water over the road and poor lighting presents a safety hazard.

Solution: Roadside ditch regrading and maintenance is needed in all ditches surrounding the intersection. Construct a 50-foot 18" culvert across 288th St E allowing drainage to the ditch on the north side ditch. It is also recommended that traffic accident records be reviewed to assess accident frequency; illumination of the intersection should be considered.

CIP12SF-PIP01: "47th Ave E Conveyance Improvements"
(296th St. E and 47th Ave. E)
Cost: $34,000 Score: 60

Problem: Roadside runoff drains through an 18" road culvert under 47th Ave E. The pipe daylights on the west side of 47th Ave E. and then flows through a 12" pipe on private property. During large storm events, stormwater often bypasses the 12" private pipe and travels overland through the private property, washing out a driveway.

Solution: Replace the existing 12" pipe with 170 feet of 18" pipe and install a catch basin with a solid locking cover to connect the existing 18" culvert under 47th Ave E. A 5-foot drainage easement extending 170 feet through a low-density residential area (0.02 acres) should be acquired. In addition, install a 60-foot 12" culvert along 296th underneath its intersection with 47th Ave E.

CIP12SF-DIV01: "Mountain Highway Conveyance Improvements"
(Christensen Muck Road and SR 7)
Cost: $319,000 Score: 95

Problem: Several homes located in the vicinity of Christensen-Muck Road experience flooding resulting from runoff passing through a large culvert under Mountain Highway (SR 7), south of 340th St. E, which can also flood Christensen-Muck Road, itself.

Solution: Install a flow splitter at the upstream end of the existing culvert under Mountain Highway. Convey high flows along the west side of the highway via 730 feet of 24" pipe and 490 feet of drainage ditch directing the high flows north directly to the South Fork. The completed project would be monitored to see if additional improvements are warranted. A second phase of this project may be an infiltration pond. This involves work under a State Highway and should be coordinated with WSDOT.

CIP12MS-INF01 : "288th St. S Infiltration Pond"
(288th St. S and 11th Ave. S)
Cost: $297,000 Score: 115

Problem: A large drainage area in the vicinity of 288th St S, west of 8th Ave S, drains through an existing drainage channel and passes through a culvert under 288th St S. A short distance downstream, the culvert terminates in a shallow-ponding area on Fort Lewis property with no outlet. Both the road culvert and the drainage channel tend to pond under higher rainfall conditions. As a result, 288th St S is flooded during periods of most winters.

Solution: Construct a 30 acre-ft infiltration pond with a depth of 8 feet. The pond would be located on vacant land located immediately west of the existing culvert on the south side of 288th St E. This would require the acquisition of 5 acres of land.

CIP12LC-RD01: "336th St S Grade Change"
(336th St. S and 14 Ave. S)
Cost: $303,000 Score: 150

Problem: A low point exists on 336th St S about 2,200 feet west of 8th Ave S. Wetlands lie on either side of the road at this point. 336th St S frequently floods, forcing the County to close the road.

Solution: Raise the road an average of 1.5 feet along a length of 1,700 feet to eliminate the low point and the associated flooding. A detailed site survey and hydrologic/hydraulic investigation would be carried out to delineate the adjacent wetland, topography and soil properties to determine how high to raise the road. This project could have substantial wetland impacts which would need to be mitigated.

CIP12LC-CUL01: "Schudy Rd S Culvert Replacement"
(311th St. S and Schudy Road)
Cost: $100,000 Score: 175

Problem: The lower-most Lacamas Creek culvert crossing of Schudy Rd S does not have sufficient capacity to pass the 100-year storm event and water from the creek overtops the road.

Solution: Replace the existing culverts with one 10'-11" wide by 6'-4" deep metal box culvert, 29 feet in length. The culvert is sized to allow for stream bed material in the bottom of the culvert. Install large woody debris upstream and downstream of culvert to increase stream habitat value.

CIP12SF-CUL03: "288th St E Culvert Replacement II"
(288th St. E and 113th Ave. E)
Cost: $41,000 Score: 165

Problem: A tributary the to South Fork crosses 288th St E (0.7 miles east of Meridian E) through a 36" diameter concrete culvert. The culvert does not have sufficient capacity and flood waters can overtop the road.

Solution: Install a 43-foot long 6' x 5' Concrete Box Culvert to convey the 100-year, 24-hour storm event. The culvert is sized to allow for stream bed material in the bottom of the culvert.

CIP12SF-CUL04: "288th St E Culvert Replacement III"
(288th St. E and 95th Ave. E.)
Cost: $133,000 Score: 170

Problem: A tributary to the South Fork crosses 288th St E (0.4 miles west of Meridian E) through two 24" concrete culverts. The culverts do not have sufficient capacity to pass the 100-year storm event and water from the drainage channel overtops the road.

Solution: Replace existing culverts with two 44-foot long 6' x 5' Concrete Box Culverts to convey the 100-year storm event. The culvert is sized to allow for stream bed material in the culvert bottom. Raise the road grade to pass over the culvert top.

CIP12SF-CUL05: "Meridian East Culvert Replacement"
(277th St. E and Meridian)
Cost: $46,000 Score: 195

Problem: A tributary to the South Fork crosses Meridian E (north of 288th St E) in a 36" diameter concrete culvert and an 18" diameter concrete culvert. The culverts do not have sufficient capacity to pass the 100-year storm event and water from the drainage channel overtops the road.

Solution: Construct a 41-foot long 7' x 5' Concrete Box Culvert to convey the 100-year storm event. The culvert is sized to allow for stream bed material in the culvert bottom. This involves work under a State Highway and should be coordinated with WSDOT.

CIP12NF-XXX: "Graham Regional Stormwater Facility"
(224th St. E and Meridian)
Cost: $2,500,000* Score: 200

Problem: A natural low spot within a large privately-owned, undeveloped area located along 224th St E., one-half mile west of Meridian, currently receives runoff from a large area of developed and undeveloped land in the Graham area. Natural infiltration at this site currently handles most storm events. During large storm events the site is flooded. One small infiltration basin has been excavated on the west side of the flooded area. A mobile home park lies a short distance further west while a subdivision lies a short distance to the north. Possible future development may impact the infiltration which occurs at this site, potentially causing flooding to adjacent areas.

Muck Creek Basin Plan
Pierce County, Washington

CIPs
- Culvert/Pipe system
- Detention/Infiltration Pond
- Other
- Stream/Riparian Habitat
- Basin Boundary-Original
- Water Body
- Creek
- Roads
- Railroads
- Ft Lewis

N W E S

6000 0 6000 Feet

\\simba\PROJ\155905\GIS_gen\apr_gen\drainage_complaints.apr 02/05/03 CB

Johnson Marsh
Shaver Lake
Muck Creek
Dailman Lake
Hamilton Lake
Exeter Springs
Chambers Lake
CIP12LC-STR03
Lacamas Creek
8TH AVE S
224TH
288TH
CIP12MS-INF01
CIP12LC-STR02
CIP12LC-CUL01
CIP12LC-STR01
CIP12LC-STR05
CIP12LC-STR04
CIP12LC-STR04
336TH ST
CIP12LC-RD01
TISCH
KINSMAN RD
SR702
EATONVILLE CIRCLE
8TH AVE E
CIP12NF-INF01
CIP12NF-CUL02
70TH AVE
CIP12NF-CUL03
CIP12NF-STR01
North Fork Muck Creek
CIP12SF-STR01
CIP12NF-STR02
South Fork Muck Creek
CIP12SF-PIP01
MOUNTAIN HWY E (SR-7)
CIP12SF-STR02
320TH ST
CIP12SF-DIV01
CHRISTENSEN
340TH ST
CIP12NF-CUL01
CIP12NF-INF02
224TH ST
MERIDIAN E
CIP12NF-RD01
264TH ST E
WEBSTER
CIP12SF-CUL05
288TH ST
CIP12SF-CUL04
CIP12SF-CUL03
CIP12SF-CUL01
CIP12SF-CUL02
KAPOWSIN HWY
304TH ST

Figure 10-2
Recommended Capital Improvement Projects

Solution: Project ST12-01 is a study to evaluate groundwater migration in this vicinity. A solution to area flooding problems will be developed after the study has been completed and reviewed. *The estimated cost of this solution is not yet known. This planning level cost estimate is based upon the estimated cost of a 12' deep, 10.7 acre infiltration pond that had been proposed as a possible solution, however the ultimate solution and cost may differ.

CIP12LC-CUL02 "Highway 507 Culvert Replacement"
(Highway 507 and Lacamas Creek)
Cost: $345,000 Score: 215

Problem: Lacamas Creek crosses under Highway 507 through three 4-foot high arch culverts. On several past occasions, high flows have overflowed the highway at a low spot in the road, south of the culverts. This has disrupted highway traffic and caused downstream flooding and creek damage.

Solution: Replace the existing triple arch culverts with a 20'x5' concrete box culvert convey the 100-year, 24-hour storm event and meet the current Pierce County design standards. The culvert is sized to allow for stream bed material in the bottom of the culvert. During detailed design, the low spot in the highway, south of the stream crossing, needs to be factored into the design.

Water Quality and Habitat Improvement

The following capital improvement projects are included to address water quality and stream habitat problems in the Basin. Many will have added benefits, such as flood hazard reduction. Sites will be identified as part of a comprehensive land acquisition program which focuses upon flood reduction, water resource protection and habitat protection and improvement. Projects will be developed as sites are evaluated and prioritized on an annual basis. Projects may involve partnering with others to accomplish program goals. There are three main "Project Reaches". Projects will include acquisition and/or restoration.

Project reaches:

North Fork: The headwaters of the North Fork are in the Graham area, adjacent to Patterson Springs, from which it flows west to its confluence with the South Fork on Ft. Lewis. The North Fork is a perennial system, with year round flow. Anadromous fish are unable reach the North Fork due to the intermittent nature of the Mainstem. Most of the land use in the upper reaches of the North Fork is residential, becoming more rural downstream.

Mainstem**:** Most of this reach of the stream is located within the boundaries of Ft. Lewis, or the City of Roy, outside County jurisdiction. For purposes of this study, the Mainstem is defined as that area of Muck Creek below the confluence of the North and South Forks on Ft. Lewis. The creek flows west and south through Ft. Lewis, through wetland areas and man-made impoundments to Muck Lake, in unincorporated Pierce County, just north of Roy, where it merges with Lacamas Creek and through the City of Roy, then back onto Fort Lewis to its mouth at the Nisqually River. The Mainstem currently contains the best fish habitat in the

system. Portions of the stream, especially near Highway 507 are dry for significant parts of the year, limiting upstream migration of anadromous fish.

Muck Lake has become choked with vegetation to the point that it has become a fish passage problem. The Nisqually Indian Tribe, Muck Creek Council and Pierce Conservation District have already done some rehabilitation work in the Mainstem area. For purposes of the Plan CIP, the Mainstem will be part of the North Fork project reach.

Lacamas Creek: Lacamas Creek originates at about 300 th St. S. and 8 th Ave. S, in the southwestern portion of the basin. It flows northwest to its confluence with the Mainstem at Muck Lake. The creek has been channelized in several areas. Much of the area it passes through is agricultural land. Local residents have indicated that it has historically not been a major fish bearing stream.

South Fork: The South Fork of Muck Creek (also known as South Creek) originates in the northeast portion of the Basin and flows south and west to its confluence with the North Fork on Ft. Lewis. It is the largest tributary of Muck Creek. It flows through a landfill site, residential development and agricultural areas. Much of the tributary is dry for periods of time throughout the year. Some channelization has occurred.

Riparian Restoration

A long-term restoration plan for Muck Creek within unincorporated Pierce County should focus on establishment of a functional riparian corridor, by large scale plantings of riparian vegetation and exclusion of agricultural activities, primarily grazing by cattle and horses, from the corridor. The program should be focused in those areas of the creek that maintain perennial flow, e.g. the North Fork, Lacamas Creek, and a two-mile segment of the South Fork from approximately 3 to 5 miles above the confluence with the North Fork. Altogether these areas include about 12 stream miles.

Cost Assumptions for Riparian Restoration

To get some idea of what might be reasonably accomplished using this approach we have developed an idealized project concept, on a 500-foot long stream segment, buffered on both sides with 100 foot of vegetation and surrounded by fencing to exclude farm animals. The total cost of this conceptual project is $62,800. The cost estimate includes the acquisition of an easement or outright purchase of property. Development of this cost estimate is described below, using a conceptual project.

A total budget amount of $3,800,000 has been set forth for restoration projects. A percentage of that total amount has been allotted to each Project Reach, based upon the number of miles of perennial flow identified within each reach area. With a budget of $3,700,000 (less $100,000 for potential wetland restoration in South Fork) and if project sites could be obtained, approximately 59 riparian restoration projects could be accomplished in the Muck Creek Basin, covering almost 5.6 miles of stream, and including approximately 136 acres of riparian re-vegetation. (To restore the entire 12 miles of stream area initially identified, a budget of nearly $8 million would be required during the 10-year plan period using these estimates. The current budget assumes no volunteer labor or contributions by other groups or agencies. The projects may, however, involve such partnerships, which could increase the amount of restoration that could be accomplished).

Conceptual Project – Cost Estimate

500 foot long stream segment, buffered by 100 feet on both sides from top of bank. This area is approximately 2.3 acres.

Fencing

Estimated fence cost for field fence (4-foot high wire mesh) is $7/foot installed. This cost estimate is based on Water Programs experience contracting for fencing as a part of capital improvement projects. An independent estimate from the Pierce Conservation District was also $7/foot installed.

Fence 1400 feet @ $7/LF	**$ 9,800**

Plantings

Costs can vary greatly, based on the suitability of the site soils, the presence of invasive species such as reed canarygrass, and plant stock specifications. In most cases we have taken a conservative approach and assumed more costly stock and difficult site conditions. We have also assumed that labor would be paid, rather than relying on volunteer labor. Cost savings would occur if bare-root stock was used, and if volunteer labor was available.

Assumptions:
Plant density of 1000 stems/acre (2300 plants/project)

2300	Potted stock (1 gallon) @ $3/plant	$ 6,900
2300	Tree tubes @ $1.25 each	$ 2,875
2300	Weed control mat @ $.75/plant	$ 1,725
460 hrs.	Labor @ $16/hour, 5 plants/hour	$ 7,360
Design/mgmt @ $5,000/project		$ 5,000
Maintenance @ 60 hours/year for 4 years ($16/hour)		$ 3,840
subtotal		**$27,700**

Land Costs (e.g., easement or acquisition)
Estimate of $11,000 per acre of undeveloped rural land **$ 25,300**

Estimated total cost per project: **$ 62,800**
Estimated cost per mile of stream restoration: **$663,000**

The standard cost estimate for wetland creation and restoration in the framework document for the purpose of project budgeting, based upon average costs is $100,000 per acre, including land costs. Actual projects may be higher or lower.

Projects:

CIP12NF-STR01: **"North Fork Habitat Restoration"**
(North Fork and Main Stem of Muck Creek within unincorporated Pierce County)

Project Description: A total of approximately 5.6 miles of potential stream restoration area have been identified within this stream reach. It is unlikely that all the potential restoration sites will be accessible. The budget would be sufficient for restoration of approximately 2.5 miles of stream reach.

Budget: $1,748,000 **Score: 380**

CIP12SF-STR01: **"South Fork Habitat Restoration"**
(South Fork of Muck Creek, a.k.a. "South Creek", within unincorporated Pierce County)

Project Description: A total of approximately 1.9 miles of potential stream restoration area have been identified within this stream reach. Some of the areas to be restored could include wetlands, for increased flow attenuation to the Creek. It is unlikely that all the potential restoration sites will be accessible. The budget would be sufficient for restoration of approximately .8 miles of stream reach.
Funds are budgeted for 1 acre of wetland restoration during the plan period.

Budget: $608,000 **Score: 365**

CIP12 LC-STR01: **"Lacamas Creek Habitat Restoration"**
(Lacamas Creek, within unincorporated Pierce County)

Project Description: A total of approximately 4.6 miles of potential stream restoration area have been identified within this stream reach. It is unlikely that all the potential restoration sites will be accessible. The budget would be sufficient for restoration of nearly 2.2 miles of stream reach.

Budget: $1,444,000 **Score: 375**

Land Acquisition

The Plan recommends the acquisition of some lands that are valuable for habitat and water resource protection. Such lands might include wetland areas, buffers areas, or areas within floodplains. For purposes of a budget estimate, an amount of $11,000 per undeveloped rural acre of land is used to be consistent with the Framework document guidelines. The cost of developed acreage would be greater, and the amount of land that could be purchased would be reduced substantially. At the time of actual land acquisition, professional appraisals will be used to establish a purchase cost. Some of these lands may later be part of a restoration project.

Projects

CIP12NF-ACQ01:
The headwaters of the North Fork of Muck Creek are at Patterson Springs, in the Graham area. The area has been under development pressure. A large amount of land in the area has been acquired by other agencies to ensure its preservation as a resource area. Approximately 350 acres of land have been identified as desirable for acquisition. Some of the purchases may involve partnerships with other agencies. It is also assumed that not all properties desired will be available. The cost estimate is for acquisition of approximately 60 acres in the Patterson Springs area.

Budget: $1,500,000 Score: 265

Programmatic Measures

Nine programmatic measures for addressing Muck Creek Basin issues are described below.

PG12-01 Conduct a Low Impact Development Pilot
A pilot would be conducted that incorporates low impact development techniques and tools. Pierce County would adopt low impact development guidelines and work with local property interests to implement those guidelines. A development project in the Graham area would be targeted for implementation of the pilot. Based upon the experience from this one or more other LID pilot projects in other basins, Pierce County would make recommendations on how low impact development guidelines might be applied in the Muck Creek Basin and throughout Pierce County. The pilot project would be a one-time event.

Cost Assumption: Includes 0.5 FTE per year for two years for a pilot project within the Basin.

Cost: **$100,000**

Application: **Basin-specific**

Score: **346**

PG00-02 Adopt Updated Stormwater Quality Standards
The Washington State Department of Ecology provided local jurisdictions, including Pierce County, with updated guidance on stormwater management standards with the issuance of the 2001 Western Washington Stormwater Manual. Pierce County Water Programs would update its current manual.

Cost Assumption: Includes 0.25 FTE as one-time, one-year cost. Prorated for the Muck Creek share of the County-wide cost (3.4%).

Cost: **$1000**

Application: **County-wide**

Score: **380**

PG00-03 Increase Inspections for Compliance with Stormwater Requirements and NPDES Permit

Pierce County Water Programs would increase the amount of inspections related to public and private stormwater facilities to ensure compliance with current regulations (including the County's Municipal NPDES permit). Both existing and new stormwater facilities would be targeted for inspection to confirm that regular maintenance is occurring and that maintenance standards and agreements are being met. When a violation is identified, inspectors would offer education and technical assistance, but enforcement actions would be taken when necessary.

Cost Assumption: Includes 6.0 FTEs per year County-wide. The estimated costs include funding to support additional inspection staff. Lifecycle cost then prorated for the Muck Creek share of the County-wide cost (3.4%).

Cost: **$204,000**

Application: **County-wide**

Score: **398**

PG00-04 Develop and Implement a Land Acquisition Program for Riparian and Wetland Habitat Protection and Flood Hazard Reduction

Pierce County Water Programs would develop a system for acquiring and managing properties for habitat protection. The program would have the following elements:

- **Standards for Property Acquisition:** Pierce County Water Programs would develop criteria for determining which properties or types of properties will be acquired.
- **Acquisition:** Pierce County Water Programs would pursue acquisition of properties through outright purchase, easements, or other legal mechanisms preferable to the property owner. Tracking streamside and/or wetland parcels as they come on the market, reviewing the current or potential habitat value of the parcels, and negotiating with sellers would be included in this element.
- **Inventory Development:** Pierce County Water Programs would maintain an inventory of desired properties and a method for tracking when they become available. Properties identified through the Basin Planning process would help build the inventory
- **Consultation with Other Stakeholders:** Pierce County Water Programs would develop standards for coordination with other agencies or groups that have a stake in acquisition sites.
- **Management:** Pierce County Water Programs would develop a program to manage properties after acquisition has occurred. The program would address

issues such as access, preventing vandalism and illegal dumping, restoration, maintenance, and liability. Pierce County may consider working with private or non-governmental agencies on managing certain parcels where appropriate.

Cost Assumption: Includes 0.5 FTE for one year to develop the inventory, establish the policies and procedures for acquisition and management. Also, 0.25 FTE per year for nine years to pursue purchases and oversee property management issues. Prorated Muck Creek share for County-wide cost (3.4%)

Cost: **$9,000**

Application: **County-wide**

Score: **389**

PG00-05 Develop and Implement Program to Enhance Riparian and Wetland Habitat, Water Quality and Provide Flood Hazard Attenuation

Pierce County Water Programs would develop and implement projects in riparian and wetland areas that require restoration or enhancement to improve the ecosystem function, where property owners have given permission. Property owners could grant an easement to Pierce County covering all or part of their lands for habitat enhancement purposes or sell the land outright to the County. The primary function of the program would be to manage the restoration sites contained in the Basin Plan. Duties would include identifying potential projects, obtaining access, developing restoration plans, identifying resources to help in the restoration including recruiting volunteers where appropriate or hiring contractors, ordering supplies, and publicizing planting events or completed projects. The County could form partnerships with volunteer groups and other organizations such as the Pierce Conservation District, Pierce Stream Team, Muck Creek Council, the Nisqually Indian Tribe, and Fort Lewis to restore or enhance riparian and estuarine areas.

Cost Assumption: Includes 1 FTE to establish and run the program for a 10-year period. Prorated for the Muck Creek share of the County-wide cost (3.4%). The actual site restoration costs are included in the CIP element.

Cost: **$34,000**

Application: **County-wide**

Score: **325**

PG00-06 **Develop & Implement an Education, Outreach, & Technical Assistance Program**
Pierce County Water Programs would develop a comprehensive education, outreach, and technical assistance program that includes the following elements:

- **Awareness:** Activities under this element include public notification of department activities, availability of data such as updated floodplain and groundwater information and mapping, and Basin Plan-related information as it is developed.
- **Topics:** Topics may address specific pollutants such as pathogens, metals, nutrients; or issues such as flooding, lawn and garden chemicals, native plant landscaping, or small farm management. Generally, increasing public awareness of best management practices that they can implement to reduce water quality, flooding, and habitat impacts in their Basin will be the focus of each educational effort. Emergency information related to flooding needs to be well-coordinated and easily accessible.
- **Target audiences:** Audiences would include Basin residents but may also specifically target specific stakeholders such as floodplain residents, business owners, real estate professionals, or homebuyers. Coordination with other education providers such as schools and non-governmental organizations would be addressed.
- **Methods:** Methods to distribute information may include a variety of techniques such as posting information on the internet, use of libraries and public bulletin boards, speakers, news releases, newsletters, utility bill inserts, targeted mailings, fair booth displays, billboards, Pierce County Speaks segments, and other options. These methods will be utilized based on the information to be distributed and the target audience.
- **Direct Technical/Financial Assistance**: In addition to basic awareness, Pierce County's education program could include an assistance program to directly aid residents in taking desired actions. This may include supporting volunteer monitoring programs, offering technical and financial assistance to floodplain residents, offering incentives for establishing buffers, and coordinating with other agencies that provide technical support such as the Conservation District. Additional incentives might come in the form of free native plants, discounts at local stores, free workshops, tax breaks, or other methods.
- **Coordination:** In order to efficiently communicate Water Programs messages, the education, outreach and technical assistance program will include a coordination element with other agencies, groups and jurisdictions. Coordination efforts will include other education providers but also technical staff.

Cost Assumption: Includes 1 FTE to establish and run the program for a 10-year period. Prorated for the Muck Creek share of the County-wide cost (3.4%). The actual site restoration costs are included in the CIP element.

Cost: **$111,000**

Application: **County-wide**

Score: **397**

PG00-07 **Develop and Implement a Surface Water Management Monitoring Program**
Pierce County Water Programs should implement a monitoring program that would include the following aspects:

- **Water Quantity:** The water quantity element would monitor both base and flood flows on main stem creeks and selected tributaries. Groundwater and pothole flooding would also be tracked. Specific studies or modeling may be performed to accurately identify flood hazard areas. This would include maintaining gauging stations.
- **Water Quality:** Water quality sampling for Basin Plan effectiveness should include temperature, dissolved oxygen, biochemical oxygen demand, solids, nutrients, pH, metals, oils and grease, and bacteria. Pierce County should consider occasional sampling for certain pesticides and herbicides. Specific outfalls may be identified for regular sampling and additional sampling may be done to trace sources of contamination.
- **Biological Health:** Currently, Pierce County is participating in macroinvertebrate sampling which follows the protocols established for the Benthic-Index Biological Integrity (B-IBI). This sampling program would continue unless a more effective protocol or methodology is identified for assessing biological health.
- **Habitat:** Habitat would be assessed by arranging to have all major streams surveyed at least once every five years. The Tri-County Urban Issues assessment methodology would be used to maintain consistency with surveys performed to characterize the original Basin Plans. Pierce County would compare the results of the surveys to identify any trends and to analyze the effectiveness of regulations, education programs, and incentives for protecting riparian habitat.
- **Waterbodies:** The sampling program will include methodologies for evaluating conditions in streams, wetlands, lakes, and surfacing groundwater.
- **Dissemination/Mapping:** Information collected under this monitoring program would be evaluated and shared with other appropriate agencies. Where feasible, data would be recorded in GIS systems and mapped. Pierce County would have a strategy for posting updated information on the internet.
- **Adaptive Management:** As the monitoring program generates data, that information would be shared and used to assess the effectiveness of current policies, programs, and procedures. Every three to five years, Pierce County would perform an in-depth analysis of available data and publish a report on the overall health of the Basin and on the effectiveness of existing programs.
- **Training:** Competent personnel are needed to generate reliable data. Pierce County would train existing staff, hire or consult with identified experts, work with other agency personnel with capable staff, or develop a pool of volunteers that can competently collect data.

Cost Assumption: Assumes total of 3.75 FTE County-wide plus $91,000. Lifecycle cost over 10 years then prorated for the Muck Creek share of the County-wide cost (3.4%).

Cost: **$158,000**

Application: **County-wide**

Score: **244**

PG00-08 Develop and Implement BMP Manual for Pierce County Surface Water Maintenance Activities

Pierce County Water Programs would develop a maintenance manual containing Best Management Practices for Pierce County's stormwater management facilities and would address pond, river, and levee maintenance activities. The maintenance manual would be patterned after the Tri-County transportation facilities approach and would involve practices and techniques to protect water quality and habitat while preserving flood control functions of the facilities. The manual would provide standard operating procedures for work crews. It would also be designed to achieve compliance with Pierce County's NPDES permit. Distribution of the manual will be accompanied by training sessions on its purpose and use.

Cost Assumption: Includes one-time cost for 0.5 FTE plus $7500 for a consultant contract to develop a BMP manual and an additional .10 FTE annually to support ongoing training sessions and updates. Lifecycle cost over 10 years, prorated for the Muck Creek share of the County-wide cost (3.4%).

Cost: **$7,000**

Application: **County-wide**

Score: **427**

PG00-09 Develop and Implement an Invasive Species Management Program

Pierce County Water Programs would develop a program for addressing invasive species impacts to surface waters and County surface water management facilities. A general inventory of invasive plant problems in Pierce County would be conducted and entered into Pierce County's GIS database. A Best Management Practices manual would be developed to offer guidance in identifying problematic species, information on their preferred conditions, and options for controlling each problem species. Water Programs will confer with other agencies, including the Noxious Weed Control Board, Washington State Departments of Ecology and Fish and Wildlife and the Washington State University Cooperative Extension programs in developing the guidance document. Upon completion of the guidance document, invasive species training will be provided to drainage system maintenance personnel and invasive species issues will be included in public outreach and education programs. Water Programs will survey their facilities and properties to identify the presence of invasive species and the extent to which they are impacting the facility. This information will be incorporated into division work plans. Implementation of this recommendation could also include organizing and orchestrating volunteer groups and working with other groups and agencies to conduct invasive species control such as hand or mechanical harvesting, native species plantings, and other techniques.

Cost Assumption: Includes one-time cost for .5 FTE and $7500 for a consultant to develop the BMP document, complete the inventory and data layer, and 0.1 FTE annually for ongoing volunteer organization and implementation. Lifecycle cost over 10 years then prorated for the Muck Creek share of the County-wide cost (3.4%).

Cost: **$7,000**

Application: **County-wide**

Score: **420**

Additional Studies Recommendations

This section identifies additional studies needed to fill priority information gaps in the Muck Creek Basin. Cost estimates for these studies are additive to Plan CIP and programmatic recommendations. These studies were not scored by the prioritization process due to their analytical nature as compared with preventative and corrective CIP's and programmatic recommendations.

ST12-01 **Evaluate Groundwater Flow in the Graham Area**

Pierce County Water Programs would conduct a study determine whether it is appropriate to revise the Northeast Muck Creek/Clover Creek Basin boundary to more accurately include areas where surface water that is collected and infiltrates into the ground and ultimately arrives in the Clover Creek system. The Basin delineation conducted for the Plan was based strictly on topographic analysis (i.e., surface drainage patterns), and did not include areas outside the topographic boundaries that may contribute subsurface drainage. In addition to providing a basis for determining appropriate basin boundaries, the study would include information to develop alternatives for stormwater management within this particular area. Specifically, the study should (a) confirm groundwater movement in the area; (b) determine and assess impacts of alternative solutions for stormwater management; (c) determine basin boundaries; and (d) contain a public process for local community involvement during the study.

Cost Assumption: 0.25 FTE for one year, four new 6" monitoring wells at $10,000, each, $15,000 for additional survey work; $25,000 for sub-surface technology; $20,000 for public and environmental process; and $80,000 for consultant services

Cost: **$205,000**

Application: **North Fork**

ST12-02 Identification of Flooded Depression Areas ("Potholes")

A common drainage problem in the Muck Creek Basin is flooding which occurs when runoff following intense storms collects and ponds, temporarily, in local topographic depressions which have no surface outlet. The current 5-foot contours in most of the Basin are inadequate for identifying these depressions. Two-foot topographic contours will be generated. Aerial photography will be flown shortly after a major storm event to document stormwater ponding. These photos plus the 2-foot contours will be used to map depressional areas on the County's GIS system.

This data will assist in addressing existing flooding problems and in siting new development to avoid future problems. At this time this work is recommended for the Graham area only, due to its relatively high potential (relative to the rest of the Basin) for development.

Cost Assumption: 0.25 FTE for one year

2-foot contours for a 15 square mile area: $60,000

Aerial photography following storm event: $5,000

Cost: **$90,000**

Application: **North Fork and portion of South Fork**

ST12-03 Detailed Flood Study along South Fork upstream of Mountain Highway

Periodic flooding along the South Fork of Muck Creek has impacted a number of homes located in a half-mile stretch of creek upstream of Mountain Highway. A detailed flood study starting at the SR 7 (Mountain Highway) crossing and extending one mile upstream is recommended so that options to reduce flood damage to these properties can be properly evaluated. For purposes of this study, the existing HEC1 hydrology from the 1991 County *Storm Drainage and Surface Water Management Plan* is adequate. Two-foot cross-sections are needed to define the flood area. A hydraulic model can then be applied to accurately determine flood water levels and to map flood damage. The study could then produce recommendations for flood damage avoidance or minimization.

Cost Assumption: 0.5 FTE for one year + $10,000 for additional survey work.

Cost: **$60,000**

Application: **South Fork**

ST12-04 Study of the Basin to Determine Appropriate Wetland Acquisition Sites

Wetlands are valuable surface water resources. They provide habitat, flood storage and stream flow attenuation, in addition to other functions they serve within an ecosystem. The protection and/or restoration of selected wetlands will benefit the Muck Creek system. This study would identify wetlands for acquisition and restoration purposes.

Cost Assumption: 0.1 FTE for two years + $50,000 for professional

Cost: **$70,000**

Application: **Basin-wide**

PART IV

CHAPTER 10

FINAL

SUPPLEMENTAL

ENVIRONMENTAL

IMPACT

STATEMENT

Pierce County
Department of Planning and Land Services

CHUCK KLEEBERG
Director

2401 South 35th Street
Tacoma, Washington 98409-7460
(253) 798-7210 • FAX (253) 798-7425

April 17, 2003

Dear Interested Party:

Attached is the *Final Supplemental Environmental Impact Statement (FSEIS) for the Muck Creek Basin Plan*, pursuant to the State Environmental Policy Act (SEPA), Chapter 43.21C Revised Code of Washington (RCW) and the Pierce County Environmental Regulations (Pierce County Code Title 18D). The FSEIS revises the Draft Supplemental Environmental Impact Statement (DSEIS), dated February 12, 2003, in response to comments received during the 30-day comment period. A new section (Comments Received on the Draft SEIS and Responses) has been added.

The Pierce County Department of Public Works and Utilities, Water Programs, is proposing to update the *Pierce County Storm Drainage and Surface Water Management Plan* by adopting and implementing a basin-specific update for the Muck Creek Basin. The FSEIS is issued with the Final Draft Basin Plan. The Final Draft Muck Creek Basin Plan (Basin Plan) identifies existing conditions influencing surface water and storm drainage within the Muck Creek drainage basin. The Basin Plan identifies problems, potential solutions, analyzes multiple contributing factors to problems, and recommends both structural and nonstructural solutions to address problems.

This FSEIS is prepared as a nonproject environmental impact statement per Washington Administrative Code, Chapter 197-11-442. Many proposed actions covered in the FSEIS will be subject to project-specific environmental review when implementation alternatives have been identified.

Public interest and participation in the environmental review process for this proposal was encouraged through a 30-day public comment period (February 12, 2003 through March 14, 2003). Two public meetings were held on the Basin Plan and DSEIS on March 3, 2003, at the Roy Library, and on March 5, 2003, at the Graham Library.

The Final SEIS provides a general discussion of the probable significant adverse environmental impacts of the Proposed Action and the No Action Alternative. It identifies mitigation measures which can reduce or eliminate the impacts. It also includes comments and addresses comments received during the comment period.

There is no comment period for this FSEIS. An appeal of the adequacy of the FSEIS may be filed at the Pierce County Development Center, at the Pierce County Public Services Building, 2401 S. 35th Street, Tacoma, WA, 98409 by filing a Notice of Appeal and associated $1050 filing fee by 4:30 p.m. Friday, May 2, 2003. More information regarding the appeal of an FSEIS and the associated fees may be obtained at the Development Center.

Copies of the FSEIS and the Basin Plan are also available for review at the Pierce County Library, the Pierce County Planning and Land Services Department at 2401 South 35th Street, Tacoma, Washington and at Pierce County Water Programs, 9850 64th Street West, University Place, Washington. Copies of the FSEIS and the Basin Plan are available for purchase for the cost of printing at both the Planning and Land Services and Water Programs offices. A short summary of the Basin Plan and FSEIS are available free of charge.

For additional information regarding the FSEIS, call Adonais Clark at (253) 798-7165. For information about the Muck Creek Basin Plan, call Janine Redmond at 253-798-7569.

Sincerely,

for CHARLES F. KLEEBERG
Director

CK:ld
4FSEISMuckCreekInterestedPartyLtr.doc

FINAL

SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

for the

MUCK CREEK BASIN PLAN

Prepared in compliance with the State Environmental Policy Act

April 17, 2003

PIERCE COUNTY

PUBLIC WORKS AND UTILITIES DEPARTMENT

Brian Ziegler, P.E., Director

9850 64th Street West, University Place, WA 98467-1078

TABLE OF CONTENTS

FACT SHEET

Title & Description of Proposed Action	***Final Draft Muck Creek Basin Plan.*** Pierce County is proposing to update its 1991 Storm Drainage and Surface Water Management Plan and Capital Improvement Program (1991 Plan) by adopting and implementing a Basin Plan for Muck Creek. The 1991 Plan has served as a guide for the identification, design, construction and implementation of surface water management facilities throughout the County. The Muck Creek Basin Plan provides specific strategic direction on solving flooding, water quality, and habitat problems within the Muck Creek Basin. The No Action Alternative would be to continue capital project selection on the 1991 Plan list and as annually modified. The FSEIS adds information to the 1991 *Draft* and *Final Environmental Impact Statement* on the 1991 Plan.
Location of Proposal	Unincorporated Pierce County, in the Muck Creek Basin, located within the southwest area of the County, extending roughly between Graham and Roy.
Proponent	Pierce County Public Works and Utilities, Water Programs Division
Proponent Contact	Janine Redmond, Senior Planner Public Works and Utilities, Water Programs 9850 64th Street West University Place, WA 98467-1078 (253) 798-7569
Lead Agency	Pierce County Planning and Land Services
Lead Agency Contact	Adonais Clark, Senior Planner Environmental Designee Pierce County Planning and Land Services 2401 S. 35th Street Tacoma, WA 98409-7490 (253) 798-7165
Tentative Adoption Date	Public meetings and hearings on the proposed Basin Plan are expected to be held at the Pierce County Council for adoption by ordinance in spring 2003**.**

List of Permits & Approvals Required	None for the Proposed Action. Permits for work in and adjacent to water (e.g., Hydraulic Project Approvals, shoreline permits, Section 404 permits, others) will be required for specific capital projects at the time they are proposed.
Authors & Principal Contributors	Janine Redmond, Hans Hunger, Harold Smelt, Marsha Huebner, Dan Wrye, Barbara Ann Smolko CH2MHill
Date of DSEIS Issuance	February 12, 2003
Written Comments Due	March 14, 2003
Date of FSEIS Issuance	April 17, 2003
Public Meetings & Hearings	Informational meetings on the Draft Basin Plan and SDEIS were held in Roy on March 3, 2003 and Graham on March 5, 2003. A hearing is scheduled on April 23, 2003 at 7:00 p.m. before the Pierce County Planning Commission, at the Pierce County Public Services Building, located at 2401 South 35th Street, Tacoma, WA 98409.
Date of Final Action	Action by the Pierce County Council is expected in spring of 2003.
Subsequent Environmental Review	Project specific environmental review for various construction projects and programmatic actions will be performed when implementation occurs.
Location of FEIS on "1991 Plan"	9850 64th Street West, University Place, WA 98467-1078, (253) 798-2725; or Pierce County Planning and Land Services Department, located at 2401 S. 35th St., Tacoma, WA, 98409, (253) 798-7210.
Cost of FSEIS	The FSEIS may be purchased for print cost at: Pierce County Public Works and Utilities Environmental Services Building, 9850 64th St. West, University Place, WA 98467-1078, (253)798-2725 or Pierce County Planning and Land Services Department, 2401 S. 35th St., Tacoma, WA 98409, (253)798-7210 Information regarding the Muck Creek Basin Plan may also be found at the following internet address: www.co.pierce.wa.us/pc/services/home/environ/watermenu, Select "New Basin Plans" "Muck Creek"

Summary

Pierce County is proposing to adopt and implement the Muck Creek Basin Plan (Basin Plan or Plan). If adopted, the Basin Plan would be an amendment to the County's 1991 Storm Drainage and Surface Water Management Plan (1991 Plan).

The State Environmental Policy Act (SEPA), Chapter 43.21C RCW, requires that an Environmental Impact Statement (EIS) be prepared for proposed actions that could result in probable significant adverse environmental impacts. An EIS was prepared for the original 1991 Plan to provide full disclosure of potential impacts. The EIS compared a No Action Alternative against the measures identified in the 1991 Plan.

This Final Supplemental EIS (FSEIS) is prepared for the Muck Creek Basin Plan to determine whether substantial changes in County programs resulting from Plan implementation would result in "significant adverse environmental impacts" and to take into account "significant new information" that has been developed over the past 12 years (WAC 197-11-405(4)). The FSEIS compares the implementation of the Muck Creek Basin Plan with a "No Action" alternative. The "No Action" alternative would be the continued implementation of the 1991 Plan.

This Basin Plan is one of several basin plans Pierce County is preparing to update the 1991 Plan. The 1991 Plan was adopted to provide a surface water management program. It evaluated 26 drainage basins within non-federal lands and unincorporated areas of Pierce County and identified storm water and surface water management measures. The basins were evaluated at different levels, depending upon whether they were considered to be urban or rural. The eight urban and urbanizing areas were studied in more detail. Muck Creek Basin was studied as an urbanizing area, but was determined at that time to be rural in character, meaning that projects within that Basin were less urgent for immediate implementation.

Since the original 1991 Plan was prepared, surface water management has increased in complexity. Growth in the County has made development impacts more widespread and obvious. In the early 1990s the State Growth Management Act led to the establishment of environmentally sensitive areas ("Critical Areas"), such as wetlands and streams, a requirement for protection of adjacent buffer areas, and the adoption of the Pierce County Comprehensive Plan.

There has been a growing emphasis on the protection of water quality and streams, wetlands and other environmentally sensitive areas. In the mid-1990's, jurisdictions with populations over 100,000, including Pierce County, were required to create stormwater programs under the federal Clean Water Act's National Pollutant Discharge Elimination System (NPDES) program. In the late 1990s the federal government listed Chinook salmon, bull trout and other fish species found in Pierce County waters under the Endangered Species Act. Any impact to a listed species is considered to be significant.

These factors led Pierce County to propose the Muck Creek Basin Plan. This Basin Plan evaluates current conditions and problems and prioritizes recommended projects. It addresses changes in policies and planning efforts needed to meet the requirements of the Clean Water Act, the Endangered Species Act and the Growth Management Act.

The purpose of the Basin Plan is to create a basin specific, comprehensive approach to reducing flood hazards, improving fish and wildlife habitat, and improving water quality

throughout the Basin. The Plan provides a more detailed analysis of flooding and drainage and water quality problems within the Basin than the 1991 Plan. The Plan also addresses fish habitat concerns. Citizens within the Basin provided input to the Plan at public meetings, and their concerns regarding water quality and quantity in the creek were addressed within the Plan.

The Plan proposes several projects to reduce flooding and drainage problems within the Basin. It also proposes projects to improve water quality and improve fish habitat through a series of stream and riparian restoration projects. Some projects will be part of the Water Programs CIP, others may be completed as part of a maintenance program or by other agencies. The list includes:

- Twelve culvert improvements
- Two infiltration basins
- Increasing the height of one road
- Local drainage improvements
- Up to as much as 5.6 miles of riparian habitat restoration/protection projects

The first four sets of measures address existing flooding and drainage problems in the Basin. The last set of measures address fish habitat and water quality needs of the streams. In addition, recommendations for programmatic measures, Best Management Practices (BMPs) and public involvement options are presented. There are also recommendations for additional studies to address issues that could not be resolved within the scope of the planning effort. Actions by other agencies and interested parties which are supportive of the Plan are identified. Future Basin land uses and growth, according to existing planning documents, are reviewed and determined to be compatible with the maintenance of stream hydrologic conditions. A long-term monitoring plan is also presented to document the effectiveness of Basin management actions and allow for adaptive management to meet changing conditions.

FSEIS Supplements 1991 EIS; Non-project and Phased Environmental Review

This FSEIS is based on information provided in the 1991 Plan EIS. However, because some of the information provided in the 1991 EIS has changed or was not complete, this SEIS provides new and additional information to assess the impacts of the Basin Plan. Many potential impacts from Plan implementation were evaluated within the original 1991 EIS and will not be addressed again here. Copies of the 1991 Storm Drainage and Surface Water Management Plan and the 1991 Environmental Impact Statement are available for review at the Pierce County Water Programs office located at 9850 64th Street West, University Place, WA 98467-1078, (253) 798-2725 and at Pierce County Planning and Land Services Department, located at 2401 S. 35th St., Tacoma, WA, 98409, (253) 798-7210.

This Plan is considered a non-project proposal, per WAC 197-11-704 and WAC 197-11-774. The environmental review in this FSEIS is programmatic, and future project-specific SEPA review will be required, as appropriate, as specific recommendations are implemented.

Format of FSEIS

This FSEIS is a section of the overall Muck Creek Basin Plan (Part IV). Because much of the Plan includes detailed descriptions of the environmental components of the Plan, the FSEIS frequently summarizes and/or refers to the three other sections in the Plan:

> Part I of the Muck Creek Basin Plan is the "*Basin Characterization Report.*" This Report describes the environmental attributes throughout the Watershed focusing on stream reaches, associated wetlands, sensitive areas, listed and non-listed fish habitat, areas of localized flooding, and future land use changes as related to environmental degradation. Therefore, the Affected Environment sections of the SEIS summarize and refer to specific sections of the "*Basin Characterization Report"*, where appropriate. Other environmental elements not addressed in the Basin Plan are summarized based on the 1991 EIS and any new information.
>
> Part II of the Muck Creek Basin Plan is the "*Basin Plan Analysis.*" This part includes analysis of the potential benefits and impacts of proposed storm water and surface water management measures. Therefore, the Impact Analysis section of the SEIS will summarize and refer to specific sections of the "*Basin Plan Analysis"*, where appropriate. The remaining environmental elements not addressed in the Basin Plan are included in the FSEIS.
>
> Part III is the actual "*Muck Creek Basin Plan*" itself. The Description of Alternatives section in the SEIS will summarize and refer to the Basin Plan, where appropriate.

This table summarizes potential impacts to elements of the environment, as discussed in the Alternatives, Significant Impacts and Mitigation Sections of this FSEIS. It is assumed that any activities that occur are conducted in accordance with applicable land use, development and environmental regulations.

Table 10-1: Comparison of Impacts

Element	Proposed Action	Probable Significant Adverse Environmental Impact?	No Action Alternative	Probable Significant Adverse Environmental Impact?
Water Resources	• Temporary reductions in water quality associated with culvert replacement projects during construction. • Net improvement in flooding and drainage conditions. • Potential for temporary water quality impacts during the removal of fish migration barriers or stream restoration projects. • Water quality would be improved by projects and actions.	No	• Temporary reductions in water quality associated with culvert replacement projects during construction. • Many flooding problems would continue to occur. • Development impacts could increase flood flows and flooding. • Potential for temporary water quality impacts during removal of fish migration barriers or stream restoration projects. • Water quality violations of stream temperature, nutrient and pathogen standards would likely continue.	• Potential
Fishery Resources	• Potential for short-term increase in stream sediment during construction of culvert replacements and stream restoration projects. • County stream restoration and enhancement projects and programs will improve salmon habitat. • Livestock access to streams would be reduced, reducing habitat impacts. • Stream culvert capacity would be increased	No	• Potential for short-term increase in stream sediment during construction of culvert replacements and stream restoration projects. • Habitat improvements would be carried out mainly by others. • Problems with habitat degradation and low channel flows are expected to worsen. • Long term impacts to streambanks and	Potential

Element	Proposed Action	Probable Significant Adverse Environmental Impact?	No Action Alternative	Probable Significant Adverse Environmental Impact?
			habitat due to livestock access are expected to continue. • Fish habitat would continue to be degraded due to loss of riparian vegetation from development and grazing livestock.	
Vegetation	• Stream banks would be revegetated to improve habitat, reduce water temperatures and improve water quality. • Temporary impacts to vegetation may occur during construction activities. • Improvements to riparian buffers will result in a net increase in riparian area and vegetation.	No	• Vegetation will continue to be impacted in developing areas of the Basin with no coordinated plan for protection. • Temporary impacts to vegetation may occur during construction activities • No improvements to existing condition	No
Wildlife	• During construction activities wildlife may be temporarily displaced. • Removal of invasive and non-native plants species during restoration projects may result in temporary displacement of wildlife species due to loss of cover. • Habitat acquisition and enhancement will aid wildlife.	No	• During construction activities wildlife may be temporarily misplaced • Removal of invasive and non-native vegetation during restoration projects by others may result in temporary displacement of wildlife species due to loss of cover • No improvement to existing habitat programs	No
Land and Shoreline Use	• Development would be directed away from floodplains and valuable habitat resources toward areas with fewer constraints. • Stormwater facility	Potential	• Continued reduction of riparian corridor. • Stormwater facility development would be consistent with adopted policy and regulation.	Potential

Element	Proposed Action	Probable Significant Adverse Environmental Impact?	No Action Alternative	Probable Significant Adverse Environmental Impact?
	development would be consistent with adopted policy and regulation. • Basin Plan information will guide and/or support development of land use plans that reduce impacts to water resources. • The Basin Plan is proactive in reducing development related impacts.		• Development impacts to water resources would continue, the Master Plan emphasis is on CIP development., support for land use decisions is not provided. • The existing program is reactive to development related impacts.	
Aesthetic, Historic and Cultural Resources	• Temporary aesthetic impacts associated with tree/vegetation removal for construction of infiltration ponds, detention facility and other projects.	No	• Temporary aesthetic impacts associated with tree/vegetation removal for construction of infiltration ponds, detention facility and other projects.	No
Public Services and Utilities	• During facility construction roads/lanes could be closed temporarily, resulting in potential delays for emergency vehicles. • Upgrades of under-capacity culverts would reduce the incidence of road closures due to flooding. • Implementation of projects and programs will improve public safety and reduce the need for some public services.	No	• During facility construction roads/lanes could be closed temporarily, resulting in potential delays for emergency vehicles. • Limited upgrades of several under-capacity culverts would reduce, somewhat, the incidence of road closures due to flooding. • Public safety and the need for some public services will be minimally improved.	Potential

Alternatives, Including Proposed Action

Introduction and Background

This section describes alternatives to achieve the long term goals of the 1991 Pierce County Storm Drainage and Surface Water Management Plan (the 1991 Plan). The alternatives evaluated are the **Proposed Action**, adoption of a Basin Plan for the Muck Creek Basin (Plan) and the **No Action Alternative**, continued use of the Capital Improvements Program element of the 1991 Plan as the basis for project implementation. This section also provides background on the original 1991 Plan that would be altered by the Muck Creek Basin Plan.

Background—Pierce County Storm Drainage and Surface Water Management Plan (1991 Plan)

The Pierce County Council established the County's Surface Water Management Utility in March 1988 by Ordinance 87-205. In 1991, the County adopted the original Stormwater Drainage and Surface Water Management Plan (1991 Plan). The 1991 Plan was intended to provide a comprehensive program for surface water management operations, funded by service charges. A Surface Water Management Utility was established pursuant to Chapters 36.89 and 39.34 RCW (Authorizes surface water management fees, and provides for cooperation between local agencies, respectively). It was also prepared to satisfy Washington State Department of Ecology requirements for a Comprehensive Flood Control Management Plan (WAC 173-145).

The 1991 Plan addressed all 26 of the drainage basins in Pierce County, to varying degrees. Urban areas were studied in more detail than rural basins. Eight basins were studied in detail: Gig Harbor, Hylebos Creek, Clear/Clarks Creek, Clover/Steilacoom Creek, Chambers Bay, Tacoma West/Browns-Dash Point, Muck Creek and American Lake.

The 1991 Plan includes recommendations for both structural and non-structural means of accomplishing goals and objectives. The non-structural recommendations tend to be broad and county-wide rather than Basin or study area specific. Finally, the 1991 Plan focused primarily on projects aimed at addressing then-existing flooding problems. Specific flooding projects were recommended in the 1991 Plan for a Capital Improvement Program (CIP).

The long term goals were to be goals for the life of the program. The goals are shown in Table 10-2:

Table 10-2
Goals of Pierce County Storm Drainage and Surface Water Management Plan (1991)

Goal	Description	Objectives
1.) Loss Prevent the Loss of Life, the Creation of Public Health or Safety Problems and the Loss or Damage of Public and Private Property.	Prevent the loss of life or property due to flooding events.	Nonstructural measures should be preferred over structural measures. Protection of existing facilities and structures should take preference over the protection of undeveloped lands. Land use and related regulations and zoning should reflect the natural constraints of the streams, floodplains, meander zones, and riparian habitat zones. Together, this plan, program and codes should present consistent goals and objectives.

Goal	Description	Objectives
2.) Establish and Adopt a Systematic and Comprehensive Approach	Storm water management should occur in the context of an ongoing, systematic and comprehensive approach to solving existing problems and preventing future problems.	Continue the role of the Citizens Advisory Committee or similar body in an advisory role to the Utility. The body should represent the entire County and citizens with a variety or [sic] reasons for their interest in surface water management. Strategies for surface water management should balance engineering, economic, environmental, and social factors in relationship to stated comprehensive planning goals and objective. Public understanding of the various capabilities and limitation associated with storm water management should be improved through a variety of educational efforts. The goals and objectives of the Master Plan should be evaluated at regular intervals (i.e., every 5 years) to maintain consistency with other related programs affecting the environment.
3) Minimize Expenditure of Public Funds	The need for emergency measures should be reduced or prevented through planning, and the use of structural and nonstructural measures.	A stable, adequate, and publicly acceptable long-term source of financing should be established and maintained for the Utility and the comprehensive management program.
4) Maintain the Varied Uses of the Existing Natural Drainage System Within the County	Storm water management in Pierce County should occur in the context of the varied uses associated with the natural drainage systems within the County. These include agricultural, commercial, industrial and residential, fish and wildlife habitat, water supply, open space, and recreation.	Storm water management measures should preserve to the fullest extent possible opportunities for other uses. Structural flood control measures should not obstruct fish passage. Structural flood control measures should preserve or enhance existing flow characteristics for fisheries, and other uses of the riparian zone. Flood control activities should not result in a net loss of, or damage to fish and wildlife resources, but wherever possible develop or improve the diversity of habitat.

Goal	Description	Objectives
	Preserve to the fullest extent possible, the scenic, and ecological qualities of the natural drainage system in harmony with those uses which are deemed essential to the life of its citizens, and wherever possible, enhance the instream and riparian uses of the streams, wetland and lakes of Pierce County.	Changes in land use should try to restore the lands natural character to the natural state whenever possible.
5) Prevent the degradation of the quality of both surface water and the water entering the regions aquifers.	Urbanization normally leads to a degradation in the quality of storm water runoff. This can become a problem both for the wildlife which depends on the stream system and the local populace.	The use of the natural drainage system is preferred over the use of pipelines or enclosed detention systems. The preservation of natural wetland, floodplains and streams is to be actively pursued. The County will apply for a NPDES permit and will strive to be in compliance with the requirements for the preservation of water quality. All storm water runoff from impervious surfaces should be treated before it is allowed to enter the natural drainage system, infiltrate into the ground or enter Puget Sound.
6) Coordinate with Public and Private Sectors	Storm water management measures should be compatible with the various public and private sectors affected.	Planning and design/construction of stormwater management measures should include opportunity for comment by the general public and interested agencies. The Master Plan and its updates shall provide opportunity for identification of acceptable storm water management measures. The Citizens Advisory Committee should provide input on existing or pending regulations which are incompatible with the goals of the Master Plan. Efforts should be made to work with the Cities towards standardization of regulations which impact storm water management.

Pursuit of these goals is still ongoing, and many of the objectives have been met. Most of the goals were strongly related to the planning, construction, operation and maintenance of storm drainage facilities. In addition to the Goals, the 1991 Plan established objectives for each of the 26 study areas (i.e., basins). There are four surface water management objectives for the Muck Creek Basin:

1) Prevent existing flooding problems from becoming worse;
2) Prevent stormwater problems before they occur;
3) Improve the quality of surface waters; and
4) Eliminating existing flooding problems.

Use of the 1991 Plan As Principal Focus of CIP Has Evolved

The 1991 Plan has been used as a basis for Capital Improvement Program (CIP) proposals since 1991. Projects are selected every year and adopted by the County Council as part of the County's six-year Capital Facilities Plan under the County's Comprehensive Plan. Although many of the projects still come from the original 1991 Plan, there are also many that have been developed as the result of more recent information and that were not contained within the 1991 Plan. Additionally, since the 1991 Plan was developed, the cities of University Place, Lakewood and Edgewood have incorporated and thus the County's responsibility for capital projects in those areas has been eliminated. Other cities such as Roy, Bonney Lake, and Fife have annexed adjoining areas, also diminishing the County's responsibilities. Project funding, planning, construction and maintenance activities have been affected by these changes.

The 1991 Plan was also developed before the adoption of the County Comprehensive Plan which was developed pursuant to the Growth Management Act. Zoning and other land use regulations have changed development patterns in some areas of the County, and the future growth estimates used to develop the 1991 CIP list are no longer valid. Several of the smaller projects, such as culvert replacement or maintenance activities within road rights-of-way, were completed by the Transportation Services Section of Public Works and Utilities.[1]

Finally, many of the projects proposed as part of the plan have been constructed, while others could not be constructed because development patterns have made acquisition of construction sites prohibitively expensive.

Proposed Action: Muck Creek Basin Plan

The proposed action is adoption and implementation of a Basin Plan for surface water management of the Muck Creek Basin. The Plan documents the existing condition of the Basin's water resources, identifies water resource problems and issues, and recommends a plan to improve conditions in the Basin. It includes recommendations for capital projects and programmatic activities designed to remedy existing problems and to prevent future water resource problems. Plan goals are translated into a comprehensive list of Basin needs and action recommendations, including projects, programs, and policies to address the water quality, flooding, and habitat problems identified in the Plan. Projects included in the Basin Plan would append and update the 1991 Capital Improvement Plan. Programmatic recommendations would augment the nonstructural recommendations contained in the 1991 Plan. The Basin Plan will provide guidance for Pierce County's future Capital Improvement Projects (CIPs), capital expenditures, water resource protection policies, and public education programs in the Muck Creek Basin.

The Muck Creek Basin Plan provides strategic water resource management direction within the Basin by assessing problems, proposing structural and non-structural solutions, and recommending monitoring and evaluation programs. Additionally, the Plan enables cross-basin water resource management coordination by utilizing standard protocols and evaluation criteria that transcend Basin boundaries.

[1] A determination was made after the adoption of the 1991 Plan that Transportation Services would be responsible for stormwater facilities located within road-rights-of-way, SWM is responsible for all others.

The Muck Creek Basin Plan has been developed in accordance with the framework document "Guidance for Basin Planning" prepared by Pierce County Water Programs (2000). The guidance document contains a list of prescribed tasks for preparation of a basin plan, as well as direction for completing the tasks.

The Muck Creek Basin Plan has identified the following water resource management issues and potential solutions: Recommended construction projects include:

- Twelve culvert improvements
- Two infiltration basins
- Increasing the height of one road
- Local drainage improvements

In addition, the Basin Plan includes provisions for habitat protection and improvement within the Basin, including, but not limited to, such activities as property acquisition, reed canary grass removal, fencing to limit animal access, riparian re-vegetation and stream channel habitat enhancement.

Future land use for the Basin is designated almost entirely as low density and is not expected to significantly impact stream flows. Most of the development will be concentrated in the northeast portion of the Basin in the Graham area. Low impact development techniques are recommended for new developments in this area. Onsite infiltration of stormwater is encouraged, as well.

The Basin Plan also recommends programmatic measures. Among them are:

- A habitat protection, acquisition and restoration program
- A public education, outreach and technical assistance program
- Implementation of a Low Impact Development program
- A "Best Management Practices" manual for surface water management facilities
- An invasive-species control program
- An effectiveness monitoring program

Nearly all of the perennially flowing portions of the main stem of Muck Creek are located on Fort Lewis. Long-term plans call for very little Fort development within the Muck Creek Basin. Critical salmon spawning areas in this portion of the Basin, notably Johnson Springs, Exeter Springs and the lower portion of Muck Creek are currently protected. Improvements in the operation of the Chambers Lake Dam, upstream of Roy, may help to improve flow conditions somewhat. (There have been instances where flow from the lake has been restricted and the downstream creek flow in Roy has suddenly dropped to very low levels.) The Fort is developing detailed flow and stream habitat data for that portion of the stream within its boundaries. There is the opportunity for the County and the Fort to work cooperatively in implementing stream and riparian improvements.

The Basin Plan contains recommendations for public education and a number of the habitat CIPs that provide opportunities for public involvement. The Plan also provides recommendations for long-term monitoring to document the improvements to habitat and water quality.

Finally, each project and programmatic action is prioritized in the Basin Plan through evaluation against standard criteria. The prioritization involves assignment of points related to the accomplishment of program goals and objectives. Each project or programmatic recommendation is evaluated against a series of criteria (see Appendix M of this document).

In summary, those criteria include:

- Flood reduction (level and frequency)
- Water quality improvement (source reduction)
- Natural resource improvement (restoration and protection)
- Recreational and multiple use opportunities
- Aesthetics

No Action Alternative

The "No Action" Alternative would be to continue Water Programs activities as they currently exist, using the 1991 CIP as the basis for considering its annual capital public works and work plan. As the list of high priority projects gets completed, and as the CIP becomes more dated, the County will increasingly rely upon more opportunistic means of identifying and prioritizing capital projects, such as citizen complaints and judgment of County staff.

Most of the problems within the Muck Creek Basin identified in the 1991 Plan are related to the loss of flood storage areas and undersized culverts. For the Muck Creek Basin, the 1991 CIP identified project costs totaling $1,829,000, of which $715,000 were for high priority projects (Five culvert replacements costing $343,000, and $372,000 for miscellaneous, undefined projects.) None of the projects have been completed as part of the Water Programs CIP. It appears that at least one of the listed medium priority projects and one of the low priority projects, both culvert replacements, have been completed by the Pierce County Transportation Services Division.

Table 10-3 1991 CIP High Priority Projects in the Muck Creek Basin

MC-LA-6,	Schudy Road crossing of Lacamas Creek
MC-MK-18S	SR 161 crossing of one of the South Fork tributaries
MC-MK-13S	288th Street E crossing of one of the South Fork tributaries
Mc-Mk-8SD	A second crossing of 288th Street E by one of the South Fork tributaries
MC-MK-7NA	Culvert under a gravel road, North Fork of Muck Creek

Comparison of Alternatives

Table 10-4 summarizes major characteristics of the Proposed Muck Creek Basin Plan and the No Action Alternative:

Table 10-4 Comparison of the Alternatives

Feature	Proposed Action	No Action Alternative
Flooding Solutions	X	X
Water Quality Solutions	X	
Habitat Solutions	X	
Annual Capital Facilities Element	X	X
Comprehensive, strategic	X	
Focus on specific projects		X
Focus on Basin problems	X	
Countywide programmatic or non-structural solutions	X	X
Basin-specific programmatic or non-structural solutions	X	
Prioritizes within Basin	X	
Prioritizes countywide		X

Affected Environment, Significant Impacts, and Mitigation Measures

Water Resources

Affected Environment

Muck Creek drains a 90-square mile area of southwestern Pierce County. In terms of geographic area, it is the largest tributary of the Nisqually River, accounting for one-seventh of that river basin. The average flow at Roy is 45,000 acre-feet per year (64 cubic feet per second). Two primary tributaries, the North Fork and the South Fork, join to form the Main Stem of Muck Creek. The Main Stem forms the lower 14 miles of this stream system, nearly all of it lying within Fort Lewis. The North Fork is perennial. However, nearly all of the South Fork and much of the Main Stem cease flowing during the drier portions of the year, typically July through mid-October. The presence of highly infiltrative soils throughout the center of the Basin appears to be the major reason for this phenomenon. The lower 2-3 miles of the main stem generally flow throughout the year as a result of inflow from springs. Lacamas Creek is a final major tributary, joining Muck Creek at Roy. The middle and lower portions of this stream also flow the year-round.

The water quality in the streams is good for most of the measured parameters. However, the state standards for temperature and coliforms are commonly exceeded. Low levels of dissolved oxygen occasionally occur. Riparian tree cover is lacking along long segments of the streams in this Basin, contributing to higher stream temperatures. Much of the central portion lies within a prairie where tree cover is naturally limited. Livestock practices also commonly contribute to water quality degradation. Direct access of animals to streams has resulted in severe stream bank erosion along a number of reaches in the Basin. In addition there are several instances of animal confinement areas located adjacent to streams, where there is direct runoff of animal waste to the creek. These practices contribute nutrient (nitrogen and phosphorus) and pathogens to the streams. This also results in higher levels of sediment deposition in the stream bottom that are often observed immediately downstream.

There are about a half dozen undersized road culverts where streams may overtop the roads during higher flow events. Otherwise, there are relatively few problems with direct flooding form the major streams in the Basin. The majority of the flooding problems occur due to shallow ponding in localized depressions. Further information on existing water resource conditions and problems can be found in Sections 4.4, 4.5, 5.2, 5.3 and 5.4, and Chapters 6 and 7.

Significant Impacts and Mitigation Measures

Proposed Action

The Basin Plan identifies a series of Capital Improvement Program (CIP) projects to relieve flooding and drainage problems. These include twelve culvert improvements, two infiltration basins, increasing the elevation of one road and local drainage improvements. The long-term effects of these projects would be a net improvement in the flooding and drainage

conditions in the Basin. Culvert replacement projects would result in stream crossings that meet current county road standards and substantially reduce road flooding in the Basin. None of the undersized culverts form a major upstream inundation. The stream channels downstream of these locations show no signs of serious erosion or flooding problems. Therefore, the increased culvert capacities resulting from these projects would not result in significant impacts.

The two proposed infiltration basins would be located in areas where stormwater currently naturally infiltrates. The ponds would direct surface flows to controlled areas, avoiding recurring flood damages, but would not result in a substantial increase in infiltration. These infiltration basins would not significantly change groundwater recharge or its distribution within the Muck Creek Basin.

Local drainage improvement projects generally involve the installation of short lengths of storm pipe and ditches to improve local drainage. None of these projects will have a significant long-term impact upon streams in the Basin.

As discussed in Section 9.3, water quality problems will be addressed through the riparian and stream habitat improvement projects. CIP projects are proposed that involve the establishment of riparian buffers along stream segments that are largely or totally lacking in buffer or tree cover. At several locations where there has been severe damage, stream bank restoration would occur. These measures would reduce the incidence of direct inflow of animal waste to the streams. In addition, a functioning riparian buffer would provide additional filtering and infiltration for runoff from adjacent farm or other land use activities. The effect would be a reduction in nutrients, pathogens and sediment reaching the streams and an improvement in water quality.

The tree cover associated with new riparian buffers would provide shade for the streams, lowering the water temperature increases experienced in the streams during the warmer days of the summer and early fall. This would be particularly true for the perennially flowing North Fork and Lacamas Creek, where most of the riparian restoration projects would occur. Temperature fluctuations in the streams would also be reduced. The beneficial nutrient, pathogen and sediment reductions would occur in the first several years as the ground cover within the riparian buffer became established. The beneficial stream shading effects would take several decades to take full effect as the planted trees grew to maturity.

Many of the CIP projects would have short-term water quality impacts, particularly those constructed within or adjacent to the streams. Culvert replacement would disturb the streambanks and bottom. Stream restoration, stream bank stabilization and riparian revegetation projects would also disturb streams and adjacent areas. Where these disturbed areas came in contact with flowing waters, sediment would be mobilized and quickly carried downstream, temporarily reducing water quality. Subsequent deposition of sediment could also harm fish habitat. Standard erosion control measures would be implemented to avoid serious sedimentation problems. Work adjacent to or within streams will be limited to low flow periods, typically the summertime. Stream flows could be temporarily diverted and pumped around the active project site, avoiding the disturbed areas. Standard erosion control measures such as silt fencing, coverage of exposed earth and permanent seeding of disturbed areas following construction will further reduce temporary sediment and water quality impacts. Each project will be required to meet County construction and erosion control requirements, as well as applicable state and federal requirements. For instance, those projects taking place within a stream will require a

Hydraulic Project Approval (HPA) from the State Department of Fish and Wildlife. The standard requirements for control of erosion and other construction related pollutants, such as fuels and lubricants, assure that the water quality impacts will be short-term and not significant.

As discussed in Section 9, no major development is planned for that portion of the Muck Creek Basin lying within Fort Lewis. This portion of the Basin will continue to be used for troop maneuvers and no significant future water resources impacts are expected to occur. Fort Lewis has a continuing program of riparian and wetland restoration projects that will continue to improve the flow regime and water quality within the Main Stem of Muck Creek. There appears to be an opportunity for the Fort to improve its management of flow releases from Chambers Lake. Monitoring in Roy has shown sharp, sudden reductions in flow in June of the past two years as the Fort has reduced outflow from the lake in anticipation of the summer low flow period. A more gradual reduction of lake outflows in the late spring and early summer would reduce, somewhat, the periods of very low or no flow experienced on the Main Stem of Muck Creek downstream in Roy, resulting in a beneficial effect.

Future growth and land uses within the Muck Creek Basin are discussed in Section 5 of the Basin Plan and in the Land Use Section of this document. Given the relatively low density of land uses throughout the Basin, the direct impacts upon water resources are not expected to be significant. Low Impact Development concepts have potential for application for commercial and residential development in the Roy and Graham areas. LID incorporated into new development could reduce the potential for significant future drainage problems without the need for these areas to develop major stormwater collection systems. As stated in Section 7.1, the two major water uses in the Basin are agricultural and domestic. These uses are drawn almost entirely from groundwater. Future water use in the Basin is not projected to increase substantially and will represent about 7 percent of the groundwater recharge. Therefore, water uses in the Basin are not expected to significantly impact the Basin's ground or surface water resources.

As a result of the generally level topography throughout much of the Basin, local drainage problems due to ponding of stormwater runoff are a common occurrence. Several recommended studies (Section 9) would give the county more effective information for identifying these types of problems: development of 2-foot topography throughout the Basin and aerial photos taken after a large storm event. These measures would aid the County in identifying local flood areas, allowing more effective mitigation against existing and future problems.

A low-lying area along the South Fork, upstream of SR 7, appears to be prone to flood damage during high flow events on this stream. A detailed flood study of this reach would be useful in developing specific mitigation measures to reduce this flooding.

Available information suggests that much of the groundwater which recharges in the northeast portion of the Basin (the Graham area) may move northwest, beyond the Muck Creek Basin boundaries and into the Clover/Chambers Basin to the north. Portions of the Clover/Chambers Basin experience high groundwater and flooding conditions following periods of high rainfall.

Patterson Springs is the major water source for the perennially flowing North Fork. The extensive wetlands along its upper reach are also important to its flow regime. The future development of these springs for other uses or their reduction or loss would result in a significant impact to Basin water resources. The acquisition and/or permanent protection of this critical area and the extensive wetlands comprising the upper portion of the North Fork,

as recommended in this plan, will assure the preservation of this important Basin water resource. The Cascade Land Conservancy currently owns about 100-acres in this area and is actively seeking to acquire more, including the land comprising much of the Patterson Springs.

The Basin Plan recommends a stormwater compliance assurance program, including increased inspection, technical assistance, and enforcement. This is expected to improve surface water protection.

The public education program recommended in the Basin Plan would raise the level of awareness on the part of the residents regarding the important resource that Muck Creek and its tributaries represent. Residents would also become more aware of the effects that their personal actions can have on the streams. Of particular importance in this Basin is the education of rural residential property owners to maintain and/or establish buffers alongside streams that flow across their properties. This concept can avoid further degradation of water quality and has the potential to improve water quality if embraced by a substantial portion of the rural population. The enlistment of residents to participate in stream and riparian restoration projects is also highly effective as an education tool. The Conservation District's farm water quality improvement program, focused in part on the recommendations of this Basin Plan, would also contribute to beneficial water quality effects.

Overall, implementation of the Muck Creek Basin Plan is expected to result in a major long-term benefit to the quality and water resource conditions within the Basin. No significant adverse environmental impacts are likely.

No Action Alternative

Under the No Action Alternative, stormwater would continue to be managed in the Muck Creek Basin as it is today. County efforts would continue to focus on serious drainage complaints rather than assuming a more proactive, comprehensive approach. Periodic maintenance of ditches, culverts and other county drainage facilities by County crews would continue. Up to four undersized culverts on the South Fork and the Lacamas stream systems would eventually be replaced under the existing CIP. Short-term impacts and mitigation measures from these projects are similar to capital facilities impacts discussed under the Basin Plan alternatives. However, road flooding problems could continue to occur in the Basin unless other measures are identified and taken. As further development in the Graham area occurs, drainage problems would intensify. The area east of the existing commercial center along 224th Street SE currently provides stormwater infiltration for much of the area. Its development would result in flooding problems in this area.

Ongoing riparian restoration projects carried out by Fort Lewis and the Pierce Conservation District would result in modest improvements in water quality over the long term. The farm water quality management program of the latter would also redress some of the more severe livestock water quality degradation and stream observed in the Basin over the long term. However, without a more comprehensive approach, water quality violations of stream temperature and pathogen standards would likely continue to occur throughout most of the Basin.

Fishery Resources

Affected Environment

Muck Creek supports four species of salmonids including chum salmon, resident and anadromous (steelhead) rainbow trout, and resident and sea-run cutthroat trout. Chinook salmon are not known to exist in the Muck Creek drainage area. Chum salmon are the most numerous of the anadromous fish. The run in Muck Creek typically comprises about one-third of the chum salmon run to the entire Nisqually River system. However, annual runs can vary dramatically. Muck Creek experienced extremely low flow during the fall and winter of 2000/2001. As a result, escapement to Muck Creek was essentially zero. In contrast, the 2001/2002 season had a large run of over 10,000. Only small numbers of steelhead and few, if any, Coho currently utilize Muck Creek. No federally protected fish species are present in the Muck Creek drainage, although two protected salmonid species are present in the Nisqually system (i.e. Chinook salmon and bull trout).

Anadromous fish spawning is confined almost entirely within the middle and lower reaches of the Main Stem of Muck Creek. The lower two to three miles of Muck creek has numerous pools and provides good fish habitat. Much of the rest of the stream system in the Basin provides only limited fish habitat for a variety of reasons, among them: historically dredged channels, lack of riparian buffer, lack of large woody debris, sediment deposition, channels choked with reed canary grass and no stream flow during much of the dry season. Additional information on existing conditions can be found in Section 4.6 and 5.5 and Chapter 8.

Significant Impacts and Mitigation Measures

Proposed Action

Implementation of the Basin Plan would increase the capacity of six stream culverts within the Basin. When undersized culverts are replaced, detention on the upstream sides is typically offset by improved upstream migratory passage by salmonids. During and following construction, the freshly disturbed stream channel has the potential for sediment delivery due to erosion processes. Erosion would be controlled through the application of BMP's. Using properly implemented and appropriate BMP's, short-term impacts to fish habitat would be minor. The culverts would have gravel bottoms and be engineered to meet fish passage requirements. Their installation would therefore result in a net long-term benefit to fish habitat.

Stream restoration projects are recommended in the Basin Plan CIP for the purpose of enhancing salmon habitat. Stream restoration consists of channel enhancement measures which include bank stabilization, large woody debris installation, channel relocation (meander creation), or channel widening. Stream restoration projects would also include riparian vegetation planting, extending away from the streambanks for a distance of 100' feet, wherever possible. The objective of stream restoration is to create complex habitat with adequate pools and riffles along with in-water and overhead cover in the form of LWD and riparian trees. Other objectives include shading to reduce peak water temperatures and stream bank stabilization to reduce sedimentation.

Because of the close proximity of streambanks to surface water flow, there is considerable potential for sediment delivery to streams during the first year or two following construction

activities. Whenever in-channel work is done, water would be diverted around the construction zone in a pipeline. The construction zone would be isolated with upstream and downstream barriers made of sandbags in combination with membrane water barriers. Pumps would typically be employed just downstream of the upstream barrier to insure the effective de-watering of the construction zone. Construction of this type would be done during the driest months of the year (July, August, and September) to minimize the possibility of flooding the construction area. Construction during this period also has the least impact upon resident and migratory fish.

After earthwork is completed, additional BMP's for erosion control would be employed. For instance, jute matting, coir logs, fascines, and/or hydro seeding (native wetland mix) would be used. Temporary irrigation may be employed through the first summer and fall to ensure a high-degree of survival of grass, forbes, shrubs, and tree plantings. All of these BMP's are designed to minimize erosion and subsequent sedimentation processes. All disturbed stream bottom area would be restored to clean gravel or cobble. In areas where the stream bottom disturbance results in potential deposition of fine grain materials, suitable clean rounded gravel would be placed over the stream bottom to maximize downstream sediment transport during subsequent wet seasons.

Riparian planting projects differ from stream restoration in that no disturbance occurs within the channel except the upper portion of streambanks. Treatments would include the planting of willow stakes and containerized stock such as Sitka spruce, western hemlock, western red cedar, Pacific ninebark, salmonberry, red osier dogwood, and other species. Except for the willows and dogwoods, the remaining species would be planted at or above the ordinary high water mark. As the result of the noninvasive techniques used in riparian plantings, no significant short-term impacts are expected. Over the long term, substantial fishery benefits would accrue. The tree and brush canopy would provide some cover and reduce the incidence of high summer water temperatures which are potentially harmful to fish. Eventually, wood fall into the stream would provide a permanent supply of large woody debris, offering habitat complexity beneficial to fish species.

The Basin Plan recommends the establishment of an invasive-species control program. This program would result in an inventory and operations manual for use in annual control plans. A number of the CIP projects involve removal of reed canary grass as a major component. This exotic species is highly invasive, particularly in shallow, inundated areas. In the past, severe infestations appear to have blocked fish migration into Lacamas Creek and within portions of the Main Stem of Muck Creek. Reduced channel capacity has also led to flooding in the Roy area.

Temporary impacts would occur during and shortly following grass removal projects. Physical excavation would mobilize sediments which would cause temporarily high turbidity and likely redeposit a short distance downstream. Use of a herbicide would cause a temporary spike in the concentration of this contaminant in the water. All these effects would be temporary, generally lasting no more than a few days or weeks following completion of the project. Herbicides would be a short-lived type, such as Rodeo, approved by the State Department of Ecology for use in streams. As a result of the increased channel capacity following the project, deposited sediment would tend to flush out of the stream system during higher winter flows and should generally be gone within a few years.

A proven method for permanent suppression of reed canary grass is to shade it out with a thick overhead canopy. Therefore, riparian plantings proposed for the restoration projects would be the key to permanent elimination of reed canary grass from a project site. A

conifer (evergreen) canopy is the most effective, but willow plantings and native brush species would also suppress the grass.

Most of the riparian restoration projects would involve the installation of fencing to keep livestock away from streams. The installation of the fencing would have minimal stream impact. In addition to water quality benefits, fish habitat would be enhanced by the protection of streamside vegetation. Grazing livestock often eat riparian vegetation. It is common to have entire riparian communities stripped of all vegetation over time. Collapsed streambanks represent serious damage to salmon habitat. The physical damage resulting from livestock access to streambanks and channels would be largely eliminated. Stream habitat, both onsite and downstream, would improve. Some projects may allow for continued stream access for livestock. In these cases the access would be limited to short lengths of stream where the banks have been reconstructed to resist erosion, minimizing downstream sedimentation.

Implementation of the Basin Plan would result in long-term benefits to fish habitat within the Muck Creek Basin. Short-term impacts would be minor and would last only a short period following construction. No significant adverse environmental impacts are likely.

No Action Alternative

Under the No Action Alternative, riparian restoration and reed canary grass abatement projects would continue to be carried out by Fort Lewis and by the Pierce Conservation District. As a result, improvements in fish habitat would occur in the Basin. However, problems with habitat degradation and channel blockage by reed canary grass are expected to continue. This has been a particular problem in Lacamas Creek near Roy. Permanent control of reed canary grass will only occur through extensive revegetation of the streambanks and riparian area with trees which provide permanent stream shading. Recurring maintenance during the first years following revegetation is also necessary to assure survival of the new plants to a point where they can out-compete the reed canary grass. The current level of stream and riparian restoration is not sufficient to meet this need.

Long-term impacts to streambanks and habitat due to widespread livestock access to streams in the Basin are expected to continue. The absence of streamside vegetation and the accelerated input of sediment would continue to result in degraded fish habitat.

Short-term impacts and mitigation measures associated with capital facilities projects listed in the 1991 CIP are similar to those discussed under the Basin Plan Alternative. Significant adverse environmental impacts may occur from lack of activity.

Vegetation

Affected Environment

The plant communities in the Muck Creek Basin can be grouped into four habitat types: conifer forests, oak/mixed oak woodlands, prairies and riparian/wetland. Brief upland habitat descriptions are as follows. Further information can be found in Section 4.7.

Conifer Forests. Three semi-distinct forest types are contained within the Basin; western red cedar, Douglas fir, and ponderosa pine.

The western red cedar type occupies the moist soil regimes within the Basin, with hemlock scattered within this habitat type. The upper watershed is the area where it usually dominates.

Douglas fir dominates the majority of conifer habitats in the Basin at this time. This forest type grows in the variety of habitat conditions (soil moisture, topography) between the cedar and prairie ecotones. Douglas fir dominance within the Basin has increased at least in part due to the absence of burning practices once used to maintain the prairie habitats. This encroachment has reduced the amount of the unique prairie habitat within the Basin.

Scattered ponderosa pine forest types are present in ridge lines with pure stands accompanying dry soil conditions associated with prairie habitats. They are primarily adjacent to or within the borders of the Fort Lewis Military Reservation. These unique ponderosa pine stands are the only native stands in Western Washington.

Nearly all of the Basin's historical conifer forests are either in second growth or have been lost to agricultural and residential land uses.

Oak/Mixed Oak Woodlands. Oak woodlands range from communities of pure Oregon white oak to a mix of oak, conifer, and deciduous trees. Pure oak stands are found on the prairie edges.

Prairies. Traditional prairie habitat exists in the Basin, but in limited quantities. It is found in areas of dry soils, mostly within or adjacent to Fort Lewis lands. Land development, primarily agricultural forms such as dairies and pasture uses for livestock, have modified the traditional prairie vegetation species. As stated above, fire suppression within the Basin has resulted in the encroachment of Douglas fir, resulting in a substantial reduction in prairie habitat over the past half century or more.

Riparian/Wetland. Riparian, or stream-associated habitat lies along many of the streams within the Basin. Wetlands can be found throughout the Basin (see Figure 4-1). They are often associated with the streams. However, large numbers of wetlands occur within topographic depressions which can pond during the Wet Season. This habitat is particularly productive for wildlife and there are County regulations to protect it from development. However historic agricultural practices and past development have greatly reduced both the quality and the amount of this habitat.

Agriculture and fire suppression have significantly modified the species composition in the Basin. With these changes in land use invasive plants have establish themselves throughout the Basin, most notably Scot's broom and bent grass.

The Muck Creek Basin contains White-top Aster (Aster curtus), a Washington Sensitive Species and federal Candidate Species. Four other state sensitive species occur within the Basin, they are: 1) bristly sedge, 2) green-fruited sedge, 3) small flowered trillium, and 4) golden paintbrush.

Significant Impacts and Mitigation Measures

Proposed Action

Many of the CIP projects involve upgrades to the local ditch and culvert drainage system and would have minimal impacts on vegetation. The culvert upgrades proposed for several of the stream road crossings may impact some riparian vegetation adjacent to the creek. These disturbed areas would be restored and revegetated upon construction completion.

Two infiltration basins (CIP12MS-INF02 and CIP12NF-INF01) are proposed. More than half of this area is occupied by second growth forest, predominantly Douglas fir. This is a very common vegetation type in the Basin and its removal would not have significant impacts to its overall abundance.

CIP projects involve upgrading or restoring a riparian buffer up to approximately 14,000 linear feet of stream. The actual amount will be determined by availability of funds and willing landowners. If fully implemented, this would result in potentially 5.6 miles of significant additional riparian area in the Basin. This type of habitat is badly lacking in Muck Creek Basin (as described in Section 10.3.2) and its establishment would have a substantial beneficial effect. Some of the CIPs are located in current or former prairie areas. Integration of oak woodlands and prairie vegetation complexes into the riparian restoration plans for these projects would be beneficial in light of the limited amount of this type of habitat.

The County would develop a plan for acquiring existing riparian areas, wetlands and associated springs in areas such as the upper portion of the North Fork, around Patterson Springs. Preservation of this environmentally sensitive area would be a beneficial effect of the Basin plan. The Plan would include processes for coordination with non-profit agencies.

Portions of some stream/riparian restoration projects lie partially within wetland areas. Their construction would likely impact wetlands temporarily. However, many of these areas have undesirable species such as reed canary grass or have been heavily impacted by livestock or other agricultural activity. The CIPs would be designed to enhance and restore wetland areas which are associated with the riparian buffers. This would, once again, result in a beneficial environmental effect. Also, the invasive-species control program recommended in the Plan would significantly improve opportunity for native species growth within the Basin.

CIP12LC-RD01 would involve raising the road grade through an existing wetland for a distance of up to 1,700 feet. Implementation of this project would result in the permanent loss of wetlands. Alternatively, low, vertical walls could be used to minimize or perhaps avoid wetland loss. Pierce County regulations require that lost wetland be replaced. Should this CIP proceed, a wetland mitigation plan will be developed to assure that there are no significant impacts.

Overall, no significant adverse impacts to vegetation are expected to occur.

No-Action Alternative

Development will generally continue at the rural densities currently seen within the Muck Creek Basin. Major changes in the vegetation patterns resulting from long-term development in the Basin are not likely to occur, except possibly in the developing Graham area in the northeast portion of the Basin. The past trend of transition of prairie areas to forest may continue to occur. Some increase in riparian and wetland habitat will occur as a result of current County and Fort Lewis restoration efforts, although at a slower rate than under the Basin plan. Significant and Mitigation Measures of capital facilities projects are similar to the Basin Plan Alternative.

Wildlife

Affected Environment

The Muck Creek Basin yields a mosaic of wildlife habitat. The variety of habitat types results from the marine influence off Puget Sound, the glacial plains (soils) and associated vegetation, and various hydrological and topographic features in the Basin.

In the Muck Creek Basin there are: 53 mammal species, 164 bird species, 9 reptile species, and 11 amphibian species. Black bear, cougar, blacktail deer, elk, raccoon, coyote, and a variety of bats and rodent species commonly inhabit the forests. Prairie habitats provide food and cover for small to medium sized mammals such as mice, shrew, voles, cottontail rabbits, and coyotes with occasional blacktail deer. Oak woodlands offer critical habitat for band-tail pigeons, western gray squirrel and great-horned owls.

Prairie habitat contains raptors of several species (redtail, northern harrier, etc.) to the American robin to the migrant violet-green swallow. Waterfowl, primarily geese and ducks, inhabit prairie communities as foraging grounds. Of particular interest is the recovering Western bluebird population, a state designated Monitor Species, within the Basin. Extensive nesting box management has helped provide adequate nesting habitat for this species, which depends greatly upon open grasslands (prairies) to forage.

A number of species are in decline and have special state or federal designation, also referred to as Species of Concern. These include 3 mammal, 9 bird, 1 reptile, and 2 amphibian species. The peregrine falcon, bald eagle, northern spotted owl and marbled murrelet are federally listed as threatened species. Further information can be found in Section 4.7 of the Basin Plan.

Significant Impacts and Mitigation Measures

Proposed Action

Adoption and implementation of the Basin Plan would not have a major negative effect upon the habitat conditions within the Muck Creek Basin (See Section 10.3.3.2 of the Plan). The Basin Plan would result in the permanent removal of a small amount of upland forest which is in plentiful supply within the Basin, would also result in improvements in the quality and amount of critical habitats, particularly wetlands and riparian areas. Animals dependant upon these areas would likely benefit.

No significant adverse impacts to wildlife are expected to occur as a result of implementation of the Basin Plan.

No-Action Alternative

Long-term development will for the most part remain at the rural levels currently seen in the Basin. Some decrease in wildlife numbers may occur, particularly in the Graham area, where much of the future Basin development is likely to be concentrated. As the prairie areas continue to decline, wildlife associated with this habitat can be expected to decline, also.

No significant adverse impacts to wildlife are expected to occur as a result of the No Action Alternative.

Land and Shoreline Use

Affected Environment

Land Use

Existing land uses within the Basin are primarily of a rural residential character. The Basin is within the designated Rural area of the Pierce County Comprehensive Plan (Comprehensive Plan) which was prepared pursuant to the State Growth Management Act (RCW 36.70A). Approximately 25% of the Basin is within the jurisdiction of Ft. Lewis, a very small portion is within the City of Roy. Approximately 32% of the remaining Basin area was shown as residential development on 2001 County maps of existing land use, with another 37% being, agricultural, resource and open space lands. The zoning map for the area, developed as part of the Comprehensive Plan shows that almost 53% of the Basin is zoned "Rural 10" (maximum of 2.5 units per 10 acres, if 75% of the property is designated as open space), 11.2% is zoned "Rural 5" (maximum density of 2 units per 5 acres when 50% of the land is designated as open space), and 9.3% is zoned "Agricultural" (maximum residential density of one unit per 10 acres). A small portion of the Basin (0.6%) is zoned "Reserve Ten", in the northern area of Graham. This designation is to recognize lands at the edge of the Urban Growth Area, that might become "Urban" in the future. Although the maximum density allowed while it is "Rural" is one unit per 10 acres, the maximum lot size if it is subdivided is 12,500 square feet in area. The remainder of the tract is to be set aside for future development. Zoning maps designate approximately 0.8% of the Basin as commercial use areas.

The amount of existing impervious surface area within the Basin, estimated from the maps of existing land use (Figure 4-3 in the Plan), averages 7.3% (including Ft. Lewis and Roy). Impervious surface area calculations, performed for the four main sub-basins (Muck Creek Mainstem, Lacamas, South Fork Muck Creek, and North Fork Muck Creek) range from an average of 6.3% to 10%. The highest density development is around Roy (12%) and Graham (10%). If the Basin were to be developed in accordance with existing zoning, calculations indicate that impervious surface areas should increase by only 1.6*%.*

Shoreline Master Program and Shoreline Management Use Regulations

Approximately 6 miles of the South Fork of Muck Creek, starting in the SW 1/4 of Section 8, Township 17 North, Range 4 East and ending at the Ft. Lewis boundary, are subject to Pierce County Shoreline Management Use Regulations. The stretch of creek has been designated as "Rural", which is a designation intended to protect agricultural land from urban expansion, restrict intensive development along undeveloped shorelines, and encourage the preservation of open spaces and opportunities for recreational uses compatible with agricultural activities (Shoreline Master Program for Pierce County, 1974).

A very short stretch of Muck Creek, at the city limits of Roy, extending to Muck Lake is designated as Rural-Residential, as is Muck Lake (Shoreline Master Program for Pierce County). The Rural Residential Environment designation is assigned to allow for a natural transition between sometimes incompatible intensive land uses of urban area and the agricultural uses, recreational uses, and open space found in the rural environment (Shoreline Master Program for Pierce County). Construction activities within the defined shoreline jurisdiction are subject to review and permitting requirements of the Pierce County Shoreline Management Use Regulations, Title 20 of the Pierce County Code.

Comprehensive Plan

The Comprehensive Plan for Pierce County Washington (Comprehensive Plan) contains land use and planning policies. The following planning and stormwater management policies are derived from Comprehensive Plan policies:

- Provide urban level facilities and services only within the designated Urban Growth Area.
- Maintain the adopted level of service standard (LOS) for stormwater facilities. According to the Capital Facilities Element of the Comprehensive Plan, stormwater conveyance is to be designed for a 25-year, 24-hour design storm. Holding facilities for runoff are to be designed for a 100-year, 24-hour design storm or a 100-year, 7-day design storm, whichever result in a larger facility. Water quality treatment is to be designed for a 6-month, 24-hour design storm. Stormwater runoff projections used for forecasting future stormwater facility and identifying non-structural alternatives in the basin plans are based on the LOS in the Comprehensive Plan.
- Maintain compatibility between facilities and adjacent land uses.
- Foster and retain community character.
- Nonstructural measures should be preferred over structural measures.
- Involve the public and others with a stake in the outcome in water quality and stormwater management planning.
- Use of natural drainage systems for runoff is preferred over construction of facilities.
- Manage and plan water resources on a watershed basis.
- Support community education to conserve water resources.
- Provide for buffers of undisturbed vegetation in all new facility developments next to streams, ponds, lakes and Puget Sound.
- Pursue public acquisition of critical fish and wildlife habitat areas.
- Map all flood hazard areas.
- Maintain existing flood control structures on Pierce County rivers and streams.
- Evaluate the effectiveness of existing requirements for on-site stormwater retention and detention and revise where flooding issues are not adequately addressed.
- Pursue public acquisition of flood hazard areas.
- Protect, conserve and enhance the historic and cultural heritage of Pierce County.
- Upgrade and maintain existing capital facilities.

Significant Impacts and Mitigation Measures

Proposed Action

Implementation of the Basin Plan would not be expected to significantly impact land or shoreline use in the Basin. The recommendations of the Basin Plan are consistent with or do not interfere with the policies and guidance provide above. No significant adverse impacts or cumulative impact to land or shoreline use are expected to result from the implementation of the recommendations in the Basin Plan.

No Action Alternative

Implementation of the No Action Alternative would not significantly impact land use in the Basin. However, there is an inherent inconsistency of the action recommended in the 1991 Plan ("No Action") in that the document was prepared before the County adopted its current Comprehensive Plan. The "No Action" Alternative would continue that inherent inconsistency.

Aesthetic, Historic and Cultural Resources

Affected Environment

The Muck Creek Basin contains several aesthetic views of both natural and manmade features, particularly those properties that overlook lakes and river valleys and other water bodies. The Basin also includes several parks and natural areas that provide views and open space. Two parks are located in the Basin: Frontier County Park and Roy Street Park. A search of the Office of Archaeology and Historic Preservation's (OAHP) database was conducted to determine if any areas within the Muck Creek Basin were registered as historic places. No federal or state listings were found to occur within the Basin. The Pierce County Historic Preservation Program Coordinator was contacted to determine if any properties within Muck Creek Basin were listed in the Pierce County Register of Historic Places; no listed properties were found. In addition, the Pierce County Cultural Resources Inventory was searched for properties within Muck Creek Basin. That search did not identify any properties that are listed in the Pierce County register, but did identify 70 properties that are eligible to be listed in the Pierce County register. No known cultural resources are located within the Muck Creek Basin.

Significant Impacts and Mitigation Measures

Proposed Action

The Basin Plan includes a collection of recommendations to manage stormwater within the Muck Creek Basin. Many of these recommendations include regulatory action, stormwater BMPs, studies and public education programs that would likely not affect aesthetic, historic, and cultural resources in the Muck Creek Basin. The proposed Capital Improvement Program (CIP) includes a list of specific projects, ranging from culvert improvements to stream/riparian habitat improvements that would involve some type of construction activity. Culvert replacement and curbing would not cause significant impacts. Stream and riparian habitat restoration would add vegetation alongside water bodies and would improve the aesthetic views of those areas. The three proposed infiltration ponds would remove vegetation, generally second-growth forest. This would have a short-term impact. However, these sites would be revegetated and landscaped, as appropriate, to mitigate any aesthetic impacts. No significant adverse impacts to park views are expected.

No known cultural resources are located in the Muck Creek Basin. However there is a potential to encounter cultural resources during construction. If any cultural resources are

discovered during construction activities, the County would immediately consult with the OAHP in Olympia and other appropriate officials regarding appropriate measures. These would include conducting investigations of cultural resources that could be affected on the project site and identifying appropriate mitigation prior to proceeding with any work that could adversely affect cultural resources.

No Action Alternative

Under the No Action Alternative, stormwater would continue to be managed in the Muck Creek Basin as it is today. A limited number of culvert upgrades would eventually be constructed. No significant adverse impacts to Aesthetic, Historic, or Cultural resources would be expected. If any cultural resources are discovered during construction activities, the County would immediately consult with the OAHP in Olympia and other appropriate officials regarding appropriate measures.

Public Services and Utilities

Affected Environment

Schools

The project area is served by the following school districts: Bethel School District, Eatonville School District, and a small portion of the Orting School District. Although attendance boundaries have been established for schools within these districts, students may attend other schools within the system. The service area of each school varies with the area's population density and the schools grade level. The majority of Muck Creek Basin lies within the Bethel School District.

Medical services within Muck Creek Basin are limited to fire stations, which generally consist of fire fighters/paramedics and ambulances that transport patients to nearby hospitals. No hospitals exist within the Muck Creek Basin. The nearest hospitals include the Madigan Army Medical Center (located on Fort Lewis just south of Lakewood), Saint Clare Hospital in Lakeview, and Good Samaritan Community Hospital in Puyallup.

Fire protection and other emergency services within the Muck Creek Basin are provided by Pierce County Fire Districts #17 and #21. District #17 has two fire stations within the Muck Creek Basin, which includes its headquarters located in the City of Roy, and another station located near 8th Ave. South and 298th Street South. Graham Fire and Rescue (District #21) has a total of 5 fire stations, including its headquarters, which is located at Mountain Highway and 340th Street East, within the Muck Creek Basin.

Police protection within the Muck Creek Basin is provided by the Pierce County Sheriffs Department. The Roy Police Department in cooperation with the Mountain Detachment police station serves the entire Muck Creek Basin, including Graham, Roy, and South County areas. The Roy Police department is located in Roy (within the Basin), the Mountain Detachment station is located just outside the Muck Creek Basin, near the corner of 404th Street East and Meridian Avenue East (SR 161). The Mountain Detachment consists of a sergeant, deputies, and an office assistant.

Water

Domestic drinking water and fire protection water within the Muck Creek Basin is provided by the McKenna Water District, Rainier View Water Company, Roy Water Company Inc., the City of Roy and Graham Hill Mutual Water Company Inc. The Roy and Graham Hill systems are the two largest in the Basin and are discussed in more detail in Section 4.4. Drinking water within the Muck Creek Basin comes from three watersheds: Naches, Duwamish, and

Puyallup. It is important to mention that many of the residents within the Muck Creek Basin utilize private wells as a source for drinking water.

Solid Waste

Solid waste collection and recycling within the Muck Creek Basin is provided by three different franchises. The majority of the Basin is served by Pierce County Refuse (LeMay Enterprises). The portion of Muck Creek Basin which includes Fort Lewis, is served by Fort Lewis. A small portion of the eastern edge of the Basin is served by Murrey's Disposal. The solid waste collection rates and services are regulated by the Washington Utilities and Transportation Commission (WUTC). One solid waste landfill is located within the Muck Creek Basin, at 304th Street and Meridian Ave. East (SR 161). The Land Recovery Inc., landfill takes non-municipal solid waste including industrial, inert and demolition wood waste, and other types of non-hazardous solid wastes.

Electrical Power

Energy within the Muck Creek Basin is provided by Puget Sound Energy (PSE) and Tacoma Power.

Natural Gas

Natural gas is supplied to portions of the Muck Creek Basin by PSE.

Telecommunications

A variety of cellular communication towers exist within Pierce County, however, none of the cellular towers are located within the Muck Creek Basin. Cable television service is provided by AT&T Broadband. Telephone service within the Basin is provided by QWEST.

Significant Impacts and Mitigation Measures

Proposed Action

Implementation of some of the CIP projects would have short-term impacts upon public safety. The culvert upgrade projects and several of the local drainage projects would require road construction. Local roads may be shut down for limited periods of time during construction. However, this is not expected to last for more than a few days. Long-term public safety would be enhanced as a result of these projects. The incidence of road flooding and closures during the rainy season within the Basin would be substantially reduced. The elimination of nuisance ponding conditions would also benefit public safety and mobility in the Basin.

Because the Basin is outside the Urban Growth Area, designated by the Pierce County Comprehensive Plan, sanitary sewer service will not be extended without a Comprehensive Plan amendment.

The Plan recommends the construction of two groundwater infiltration basins. These basins would be constructed in the same areas where stormwater currently infiltrates, but would result in more controlled conditions, eliminating flooding problems. As a result, no significant impact upon the groundwater aquifers or the water systems that draw from these aquifers, would occur.

The Proposed Action would have no adverse significant impacts upon public services or utilities.

No Action Alternative

Under the No Action Alternative, up to four undersized road culverts, including one along SR 161, would be replaced. This would reduce the incidence of road flooding in the Basin and improve emergency services such as medical, police and fire. However, other existing road flooding problems would continue to impact emergency services during periods of high rainfall. No significant adverse impacts to public services and utilities are expected.

Distribution List

- Washington State Department of Ecology
- City of Roy
- Ft. Lewis
- Nisqually Tribe
- Pierce Conservation District
- Nisqually River Council
- Graham Community Planning Board
- Graham Land Use Advisory Commission
- Pierce County Library
- Washington State Department of Transportation
- Pierce County Transportation Services Division
- Washington State Department of Fish and Wildlife
- David Stroud, FEMA
- Kirk Sinclair, Washington State Department of Ecology
- Pierce County Master Builders Association
- Tahoma Audubon
- Jim Harpel
- Cindy Byrd
- Laurie Bischof
- Leland Weaver
- Buck McFadder
- Michelle Berryessa
- Herb Stumpf
- Dick Rough
- Linda Keen
- Bob DuBois
- Bud Rehberg
- Gineua Tuller
- Perkins
- Steve Thomas
- Joyce Moss
- Bryan Dorner
- Viki Steiner
- Barbara A. Rice
- Warren Olsen
- Donna Thompson
- Gerald Harlow
- Mark Weed
- Jeanette Dorner
- Roy Lampson
- Lucille Hart
- Box Holder
- Danny Rouser
- Tony Rotinlo

- L Schilter
- Don Olsen
- Arlene Haveland
- John Coulthard
- Dan Cardwell
- Dave Clouse
- George Walter
- Steve Wamback
- Don Clever
- Norma E. Woodward
- Linda Stumpf
- Bob & Becky Anderson
- Roger & Chris Dinelt
- Lee & George Cathcart
- Allan Malcom
- John Marshall
- Chip Nevins, Cascade Land Conservancy

11. References

American Public Health Association 1998, *Standard Methods for the Examination of Water and Waste*, 20th *Ed.*, United Book Press, Baltimore, Maryland.

Anderson, J.J., 2000, *Decadal Climate Cycles and Declining Columbia River Salmon*, in *Sustainable Fisheries Management: Pacific Salmon*, E.E. Knudsen, ed., Lewis Publishers, New York, New York.

Beckett, Alison, 2000, personal communication, Washington Department of Ecology, Lacey, Washington, May 10, 2000.

Beden, Mike, 2001, personal communication, Pierce County Conservation District, Puyallup, Washington, September 12, 2001.

Brown and Caldwell (1985), *Clover/Chambers Creek Geohydrologic Study for Tacoma-Pierce County Health Department*, Seattle, Washington.

Brown and Caldwell 1990, *Clover/Chambers Creek Basin Groundwater Management Program and EIS*, Seattle, Washington.

CH2M Hill 2001, *Biological Assessment - Interim Brigade Combat Team Transformation at Fort Lewis, Washington*, Bellevue, Washington.

Clause, David, 2000, personal communication, Natural Resources Division, Fort Lewis, Washington, January 19, 2000, March 7, 2000, January 18, December 13, 2002.

Comstock, Andy, 2000, personal communication, Tacoma-Pierce County Public Health Department, Tacoma, Washington, May 14, 2000, May 30, 2000.

Dorner, Jeanette, 2003, personal communication, Nisqually Indian Tribe, Department of Natural Resources, Yelm, Washington, February 4, 2003.

Dorner, Jeanette and Florian Leischner, 2002, *Riparian Vegetation Inventory and Enhancement Plan for Muck Creek on Fort Lewis Military Reservation*, Salmon Recovery Program Technical Report No. 1, Nisqually Indian Tribe, Department of Natural Resources, Yelm, Washington.

Engle, Mark Alan, 1997, *Quaternary Stratigraphy of the Nisqually Watershed and its Influence on the Annual Flow of Muck Creek, Washington. The* Evergreen State College, Olympia, Washington.

Ewbank, Mark, 2001, personal communication, Herrera Environmental Consultants, Seattle, Washington, December 18, 2001.

Graham, N.E., 1994, *Decadal-Scale Climate Variability in the Tropical and North Pacific during the 1970s and 1980s*, Climate Dynamics 10: 135-162.

Hanna, Ian and Patrick Dunn, 1996, *Restoration Goals for Oregon White Oak Habitat in the South Puget Sound Region*, The Nature Conservancy Of Washington, Seattle, Washington.

Herrera Environmental Consultants, 2002, unpublished data from Fort Lewis Stream Studies, Seattle, Washington, December 18, 2001.

Hinman, Curtis, 2001, Low Impact Development, Cooperative Extension Service, Puyallup, Washington.

Jacobs, Tom, 2000, personal communication, Director, Roy Public Works, Roy, Washington, February 10, 2000.

Kerwin, John, 2000, *Salmon and Steelhead Habitat Limiting Factors - Water Resource Inventory Area 11, Nisqually Watershed – Final Report.* Washington State Conservation Commission, Olympia, Washington.

Kleinfelder, Inc. 2001, *LRI Annual Report*, Bellevue, Washington.

Lavergne, Mark, 2000, personal communication, Tacoma-Pierce County Public Health Department, Tacoma, Washington, September 13, 2000.

Matthews, Chris, 2002, personal communication, Washington Department of Ecology, Lacey, Washington, January 22, 2002.

May, C.W., 2002, *Measures of Ecological Integrity for Salmonid Streams on Department of Defense Facilities in the Pacific Northwest: Current Watershed Conditions and Management Recommendations*, Technical Report APL-UW TR 0104, University of Washington, Seattle, Washington.

May, C.W., 1997, Effects of Urbanization on Small Streams in the Puget Sound Lowland Ecoregion, Watershed Protection Techniques 2(4): 483-493.

Meston, Kristi, 1999, *Natural Resources in the Muck Creek Watershed: A Review of Available References.* College of Forest Resources, University of Washington, Seattle, Washington.

Montgomery Engineers Inc. 1991 *Draft Pierce County Storm Drainage and Surface Water Management Plan*, Bellevue, Washington.

Northwest Hydraulic Consultants, 2002, *Flood Insurance Mapping Study for Lacamas Creek near Roy*, Seattle, Washington.

Pearson, H. E., and N. P. Dion 1979, *Water Resources of the Nisqually Lake Area, Pierce County, Washington.* United States Geological Survey, Tacoma, Washington.

Salminen, Ed, 1997, *ANA/DOD* Grant – Final Status Report. (ANA: Aid to Native Americans; DOD: Department of Defense)*, Nisqually Indian Tribe, Yelm, Washington.

SEMCON Inc. 1998, *Graham Hill Mutual Water Company Water System Plan*, Olympia, Washington.

Sinclair, Kirk, 2001, *Assessment of Surface and Groundwater Interchange Within the Muck Creek Watershed*, Pierce County, Washington Department of Ecology, Lacey, Washington.

Sinclair, Kirk, 1999, personal communication, Washington Department of Ecology, Lacey, Washington, November 2, 1999.

Solley, W.B., and R.R. Pierce 1998, *Estimated Water use in the United States in 1995*, USGS Circular #1200, Federal Center, Denver, Colorado.

Trout, David, 2002, personal communication, Nisqually Indian Tribe, Yelm, Washington, January 14, 2002.

URS 2000, *Draft Guidance for Basin Planning.* Pierce County Water Programs, Seattle, Washington.

URS 2001, *Groundwater Flooding Evaluation in Frederickson, Pierce County, Washington*, Seattle, Washington.

United States Army Corps of Engineers 1995, *Draft Federal Environmental Impact Statement (NEPA), Resource Investments, Inc. Landfill Facility, Pierce County, Washington – Volume 1.*, Seattle, Washington.

Walters, George, 2000, personal communication, Nisqually Indian Tribe, Yelm, Washington, April 10, 2000, January 15, 2002.

Washington Department of Ecology 2001, *Stormwater Management Manual for Western Washington*, Lacey, Washington.

Washington Department of Fish and Wildlife 2000, *Fish Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual*, Olympia, Washington.

Watershed Professionals Network 2002, *Nisqually River Level I Watershed Assessment (WRIA 11)*, Bellingham, Washington.

Whiley, A.J., and G. Walter, 2000, *The Review and Analysis of Water Quality for the Nisqually River and the Major Lakes of the Nisqually Basin*, Technical Report #6, Nisqually Indian Tribe, Yelm, Washington.

Whiley et al. 1994, *Water Quality Investigations of the Lower Nisqually Basin 1991-93*, Nisqually Indian Tribe, Yelm, Washington.

Williams, W., 1975, *A Catalogue of Washington Streams*, Washington Department of Fisheries, Olympia, Washington.

Wulkan, Bruce, 2001, *LID: Helping to Protect Waters as We Grow*, SoundWaves, Fall, 2001, Washington Department of Ecology, Lacey, Washington.

Zuchowski, T., 2002, personal communication, Natural Resources Division, Fort Lewis, Washington, February 27, 2002.

Glossary of Terms Used

4(d) Rule	In the federal Endangered Species Act, the protective rule promulgated by the lead federal agency at the time it makes a final decision to list a species as threatened. The 4(d) Rule can be a restatement of Section 9(a) prohibitions on take of a species, but also can specify activities which have been determined to be adequately regulated and given legal coverage for the (incidental take) of the listed species. *(Draft Tri-County 4(d) Rule Proposal 5-2002)*
100-Year Flood, a.k.a. Base Flood	The flood having a one-percent chance of being equaled or exceeded in any given year (*PCC 18E.10.050.K)*
Acre-Foot	The volume of water that covers one acre of land in one foot of water, equivalent to 325,850 gallons *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Adaptive Management	A process to evaluate plans, strategies or implementation actions to determine their effectiveness and then adapting (making positive changes) as new information or science becomes available.
Adverse Stormwater Impacts	The negative effect of stormwater on the integrity of the natural aquatic ecosystem, generally due to increasing stormwater volume, concentrating runoff and otherwise altering hydrology, or the spatial and/or temporal distribution of salmon habitats, flow rate or pollutant discharge. *(Draft TriCounty 4(d) Stormwater Proposal Glossary)*
Aggradation	A geologic process in which the rate of sediment deposition exceeds that of erosion and creates a persistent, long-term rise in the elevation of a streambed, floodplain, or other area
Agricultural Land	Land primarily devoted to the commercial production of horticultural, viticultural, floricultural, diary, apiary, vegetable, or animal products or of berries, grain, hay, straw, turf seed, Christmas trees not subject to the excise tax imposed by RCW 84.33.100 through 84.33.140, or livestock and that has long-term commercial significance for agricultural production, including poultry raising, horse farms and ranches. (RCW 36.70A.030 and*Draft Definitions from Proposed PCC Title 18 ESA Amendments)*

Alluvial	Deposited by running water. (Meehan, ed.)
Ammonia-N	Ammonia-N is a reduced form of Nitrogen that is toxic to aquatic life at higher concentrations. It is typically found in waters that are contaminated with human or animal waste. It can also contribute to depletion of dissolved oxygen in surface waters. *(Glossary of Parameters, Washington State Section 303(b) Report, 9-2001)*
Anadromous Fish	Species that are hatched in freshwater, mature in saltwater, and return to freshwater to spawn
Aquatic	Pertaining to water
Aquifer	A saturated permeable material (often sand, gravel, sandstone, or limestone) that contains and carries groundwater and acts as a water reservoir.
Assessment	The collection, integration, examination, and evaluation of information and values
Background Load	Naturally occurring amount of pollutants in a stream prior to watershed development, which is the arithmetic product of background level concentration and flow. *(1991 Storm Drainage & Surface Water Management Plan)*
Base Flow	The portion of the stream flow that is not due to storm runoff and is supported by groundwater, large lakes, and swamp seepage into a channel *(1991 Storm Drainage & Surface Water Management)*
Basin	A geographic and hydrologic sub unit of a watershed, shortened reference to drainage basin *PCC Stormwater Management & Site Development Manual, 1999)*
Bed Load	The sediment in a stream channel that mainly moves by jumping, sliding or rolling on or very near the bottom *(1991 Storm Drainage & Surface Water Management Plan)*
Bed Material	The material of which a streambed is composed
Benthic Organisms	Organisms living in or on bottom substrates in aquatic habitats *(1991 Storm Drainage & Surface Water Management Plan)*
Best Management Plan	A plan developed for a property that specifies best management practices to ensure the minimization of impacts to the environment, including the control of animal wastes, stormwater runoff, and erosion *(18E10.050, L with Amendments in Proposed Definitions for PCC Title 18, 1-2002)*

Best Management Practices (BMPs)	Physical, structural, or managerial practices which have gained general acceptance for their ability to prevent or reduce environmental impacts. *(PCC Title 19, Appendix A & in Draft Definitions for PCC Title 18, 1-2002)*
BIBI	Benthic Index of Biotic Integrity. A system for measuring the degree to which the quality of stream habitat deviates from that expected at a relatively undisturbed site. It is based upon the numbers and diversity of species of benthic invertebrates obtained from samples taken from the stream substrate.
Biological Oxygen Demand (BOD)	The quantity of oxygen consumed during the biological oxidation of matter over a specified period of time. See also Chemical Oxygen Demand. *(1991 Storm Drainage & Surface Water Management Plan)*
Buffer	"Buffer" means a tract or strip of land that separates one type, category or use of land from another. Buffers typically serve to provide a defined area between a more intensive use of land and a land use that is less intensive. Buffers are typically referenced by the associated critical area such as wetland buffer, riparian buffer, etc. *(Draft Definitions for PCC Title 18, 1-2002)*
cfs	Cubic feet per second. Units assigned to the volume of water that flows past a fixed point in a stream channel, drainage outlet or other water flow path every second; equivalent to 449 gallons per minute (gpm) *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Capital Improvement Project (CIP)	A project funded by Pierce County Water Programs intended to improve the physical plant of the drainage system, the performance of that system, and/or reduce site specific or cumulative adverse stormwater impacts *(Draft Tri-County 4(d) Stormwater Proposal 5/2002)*
Channel	“Natural or artificial waterway of perceptible extent that periodically or continuously contains moving water. It has a definite bed and banks that serve to confine water.” (Meehan)
Channel Complexity	Channel complexity describes salmon habitat. A complex channel that contains a mixture of habitat types that provides areas with different velocity and depth for use by different salmon life stages. In contrast, a simple channel contains more uniform flow and fewer habitat types.
Channel Confinement	Lateral constriction of a stream channel *(Clover Creek Basin Plan, 12/2002)*
Channel Erosion	The widening, deepening and headward cutting of small channels and waterways due to erosion caused by moderate to large floods *(1991 Storm Drainage & Surface Water Management Plan)*

Channel Migration Zone (CMZ)	The lateral extent of likely movement along a watercourse with evidence of active channel movement. Channel migration commonly occurs due to bank destabilization, rapid incision, and bank erosion. *(Draft Definitions for PCC Title 18, 1-2002)*
Channelization	The straightening, deepening, or widening of a stream channel for the purpose of increasing the stream's carrying capacity *(Draft Definitions for PCC Title 18, 1-2002)*
Chemical Oxygen Demand (COD)	A monitoring test that measures all the oxidizable matter found in a runoff sample, a portion of which could deplete oxygen in receiving waters *(1991 Storm Drainage & Surface Water Management Plan)S*
CIP	See Capital Improvement Project.
Clearing	The removal of timber, brush, grass, ground cover, or other vegetative matter from a site, which exposes the earth's surface on the site *(PCC 18E.10.050,R)*
Conservation Easement	A recorded deed restriction, or covenant, that runs in perpetuity on a parcel of land restricting the use of the property by preventing future real estate development such as residential, industrial, or commercial use. The conservation easement may allow continued current uses, including for example, residential, recreational, agriculture, forestry, or ranching, however the easement most often restricts both the current use as well as future uses of the land to some important conservation quality such as habitat preservation, open space or scenic views. Conservation easements are typically held by a Land Trust or governmental entity that manages these properties for long-term goals. *(Draft Definitions for PCC Title 18 Amendment)*
Contaminant	Any chemical, physical, biological, or radiological substance that does not occur naturally or occurs at concentrations and duration as to be injurious to human health or welfare or shown to be ecologically damaging *(PCC 18E.10.050,U)*
Conveyance Capacity	A term generally referring to the maximum capability of the physical drainage system to safely transport water (from a hydraulic perspective) *(Draft Tri-County 4(d) Rule Proposal 5-2002)*
Corridor (Landscape)	Landscape elements that connect similar patches of habitat through an area with different characteristics; for example, streamside vegetation may create a corridor of willows and hardwoods between meadows or through a forest.
Critical Areas	Wetlands, flood hazard areas, fish and wildlife habitat areas, aquifer recharge areas, and geologically hazardous areas (PCC 18E.10.050,W)

Design Capacity	Volume of water that a channel, pipe, or other drainage lines is designed to convey
Detention	Temporary storage of surface runoff either on, below or above the ground surface accompanied by controlled release of the stored water *(1991 Storm Drainage & Surface Water Management Plan)*
Detention Facility	A facility (e.g., pond, vault, pipe) in which surface and stormwater are temporarily stored and released at a controlled rate *(PC Stormwater Management & Site Development Manual, 1999)*
Developed Site	A site in which the land cover has been converted or substantially altered (through the addition of impervious surface and/or clearing and grading activities) from its original natural condition *(Draft Tri-County 4(d) Rule Proposal 5-2002)*
Development	Any man-made change to improved or unimproved real estate including, but not limited to: buildings or other structures, placement of manufactured home/mobile home, mining, dredging, clearing, fillings, grading, paving, excavation, drilling operations, or the subdivision of property. *(PC Stormwater Management & Site Development Manual, 1999)*
Development Regulations	Any controls placed on development or land use activities by a county or city, including, but not limited to, zoning ordinances, subdivision ordinances, and binding site plan *ordinances (RCW 36.70.030)*
Discharge	Flow rate of a stream or stormwater system, usually measured in cubic feet per second *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Dissolved Oxygen (DO)	DO is oxygen that is freely available in water. Adequate DO is necessary for the life of fish and other aquatic organisms. *(Washington State Section 303(b) Report, 9-2001)*
Disturbance, Natural	Events that affect landscapes, including regions, watersheds, and sites. They include floods, wildfires, landslides and volcanoes. They may vary in intensity from small-scale to catastrophic and in frequency from a few years to many decades or hundreds of years.
Disturbance, Human	Direct or indirect changes to land, vegetation, or water by people that alter their functions; negatively affect water quality, fish and wildlife habitat, soil, or air quality.
Easement	The legal right to use a specified piece of land for a particular purpose. *(PCC Stormwater Management & site Development Manual)*

Ecosystem	A biological community together with the chemical and physical environment with which it interacts.
Ecosystem Diagnosis & Treatment (EDT)	A proprietary method of diagnosing the condition of resources like salmon that uses a "rule-based" system which focuses on habitat as the unit of analysis. It estimates salmon performance by using an analytical model that predicts the numbers of fish supported by the habitat over the salmon's life history. It is an "expert system" that captures the state of existing knowledge including areas of incomplete or missing data. *(from the EDT Primer, 1995)*
Ecosystem Management	The management of human actions with a view toward preserving ecosystem integrity while maintaining sustainable benefit for human populations
Effective Impervious Surface	Any impervious surface that is connected or has the effect of being connected directly to the downstream drainage system. See also non-effective impervious area and total impervious area. *(Draft Tri-County 4(d) Rule Proposal 6-02)*
Effectiveness Monitoring	The evaluation of whether an action achieved the desired effect. For example, in a sediment reduction project, effectiveness monitoring would determine whether sediment supply was actually reduced.
Elevation	In retrofitting, the process of raising a house or other building so that it is above the height of a given flood
Embeddedness	The degree that gravel and larger sizes of particles (boulders, cobble or rubble) are surrounded or covered by fine sediment (e.g., less than 2 millimeters)
Ephemeral Stream Channel	A dry stream course, except during or immediately after extreme rainfall or surfacing groundwater due to heavy annual rainfall; often no ordinary high water mark is evident. See also intermittent stream channel.
Erosion	Detachment of soil or rock fragments by water, wind, ice and gravity *(PCC Stormwater Management & Site Development Manual, 1999).*
Evapotranspiration	The scientific term that collectively describes the natural processes of evaporation and transpiration. Evaporation is the process of releasing vapor into the atmosphere through the soil or from an open water body. Transpiration is the process of releasing vapor into the atmosphere through the pores of the skin of the stomata of plant tissue. By this process vegetation removes moisture and returns it to the atmosphere. *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*

Fecal Coliform	Minute living organisms associate with human or animal feces that are used as an indirect indicator of the presence of other disease causing bacteria *(1991 Storm Drainage & Surface Water Management Plan)*
Federal Emergency Management Agency (FEMA)	Independent agency created in 1978 to provide a single point of accountability for all federal activities related to disaster mitigation and emergency preparedness, response and recovery
Fill	Earth, sand, gravel, rock, asphalt, or other solid material placed to raise the ground elevation or to replace excavated material *(Draft Tri-County 4(d) Rule Proposal 5-2002)*
Fish & Wildlife Habitat Areas	The areas identified as being of critical importance to maintenance of fish, wildlife, and plant species, including: areas with which endangered, threatened, and sensitive species have a primary association; habitats and species of local importance; commercial and recreational shellfish areas; kelp and eelgrass beds, herring and smelt spawning areas; naturally occurring ponds under twenty acres and their submerged aquatic beds that provide fish or wildlife habitat; waters of the state; lakes, ponds, streams, and rivers planted with game fish by a governmental or tribal entity, or private organization; state natural area preserves and natural resource conservation areas. *(PCC 18E.10.050,AU)*
Fish Passage Barrier	An obstacle that prevents fish from moving either upstream or downstream, such as certain dams, weirs, floodgates, roads, bridges, causeways and culverts. *(Adapted from New South Wales Fisheries Web Site, 6-7-2002)*
Fishway	A passageway, often an ascending series of pools, designed to permit passage of salmon over dams, diversions or other obstructions.
Flood	An overflow or inundation that comes from a river or any other source, including but not limited to streams, tides, wave action, storm drains, or excess rainfall. *(PCC 17A.10.060,Y & PC Stormwater Manual)*
Flood Control	Physically controlling a river or stream by structural means such as dikes and levees, which separate people and property from damaging floodwater
Flood Depth	Height of flood waters above the surface of the ground at a given point
Flood Duration	Amount of time between the initial rise of floodwaters and their recession *(Draft Clover Creek Basin Plan, 5/2002)*

Flood Elevation	Height of flood waters above an elevation datum plane
Flood Frequency	The frequency with which the flood of interest may be expected to occur at a site in any average interval of years. Frequency analysis defines the "n-year flood" as being the flood that will, over a long period of time, be equaled or exceeded on the average once every "n" years. *(PCC 17A.10.060,Z; PC Stormwater Management & Site Development Manual, 1999; Draft Amendments to Pierce County Code Title 18)*
Flood Hazard Management	A comprehensive approach to flood control issues that encompasses both flood control management and floodplain management and uses both structural and nonstructural methods of reducing flood hazards. Flood hazard management is not limited to areas within the floodplain but can extend to the entire watershed. Stormwater management is also included because the control of the quantity and quality (sediment load) of stormwater runoff into streams and rivers can have significant impacts on stream and river flooding.
Flood Insurance Rate Map (FIRM)	"Flood Insurance Rate Map (FIRM)" means the official map on which the Federal Insurance Administration has delineated areas of special flood hazard and the risk premium zones applicable to Pierce County. *(Draft Definitions for PCC Title 18, 1-2002)*
Flooding or Erosion Impacts	Impacts such as flooding of septic systems, crawl spaces, living areas, outbuildings, etc.; increased ice or algal growth on sidewalks/roadways; earth movement/settlement; increased landslide potential; erosion and other potential damage *(Draft Tri-County 4(d) Rule Proposal 5-2002)*
Floodplain	Total area subject to inundation by the base flood including the flood fringe and floodway. Low area adjoining a stream or river channel that overflows at times of high river flow. *(PCC 17A.10.060, AE*
Floodplain Management	Management of areas within the floodplain, which includes resource protection, environmental enhancement, flood damage protection and land use regulations
Gaging Station	A selected section of a stream channel equipped with a gage, recorder, or other facilities for measuring stream flow *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Gaining Stream	A stream or reach of a stream where surface flow is increasing due to inflow of ground water, also known as an effluent stream *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
gpm (gallons per minute)	The volume of water that will flow in a minute; equivalent to .0022 cubic feet per second *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*

Geographic Information System (GIS)	A computer based information system that stores parcel data for specified land masses. Information can be retrieved in several formats that include computer generated maps, reports, etc. *(PCC Title 19, Appendix A)*
Geologic & Geomorphic Processes	The actions or events that shape and control the distribution of materials, their states and their morphology within the interior and on the surface of the earth.
Geomorphology	The geologic study of the shape and evolution of the earth's landforms.
Glacial Outwash	Sand and gravel which has been transported and deposited by streams of water coming from glaciers, highly permeable *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002).*
Glacial Till	Surface or near-surface soil that has been compressed by a past glacier into a dense, relatively impermeable material. It typically has a low infiltration rate and is often responsible for the formation of ponds, wetlands or a seasonally high water table.
Glide	A shallow stream reach with a maximum depth that is five percent (5%) or less of the average stream width, a water velocity less than 20 centimeters (8 inches) per second, and without surface turbulence.
Global Positioning System (GPS)	A system for accurately determining the position of a point on the globe using signals from a set of orbiting satellites. Typically accurate to within 100 feet.
Gradient (of stream)	Degree of inclination of a stream channel parallel to stream flow; it may be represented as a ratio, fraction, percentage or angle.
Groundwater	The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer. *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Groundwater Flooding	The occurrence of surface and subsurface water resulting in flood inundation, due to the fluctuation of the water table. It encompasses depth, frequency, and duration and is usually seasonal by characteristic. *(Draft Definitions for PCC Title 18, 1-2002)*

Habitat The sum total of all the environmental factors of a specific place that is occupied by an organism, a population or a community. *(PCC Title 19, Appendix A)*

Habitat Protection Preservation of ecosystems with relatively natural habitat conditions by preventing future impacts from manmade disturbances.

Habitat Preservation Conservation of existing habitat, generally through acquisition of existing habitat.

Hydrologic Regime The timing, magnitude, duration and spatial distribution of peak, high, and low flows. Hydrologic regimes common in Washington include rain, rain-on-snow, and snowmelt-dominated runoff patterns. *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*

Hydrologic Soil Group A classification of soils by the Soil Conservation Service into four runoff potential groups. The groups range from A soils, which are very permeable and produce little runoff, to D soils, which are not very permeable and produce much more runoff. *(1991 Storm Drainage & Surface Water Management Plan)*

Impervious Surface A hard surface, which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development, and/or a hard surface area, which causes water to run off the surface in greater quantities or at an increased rate of flow than the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, gravel parking lots, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater. *(PC Stormwater Management & Site Development Manual, 1999; Draft Tri-County 4(d) Rule Proposal 5-2002; Draft Definitions for PCC Title 18, 1-2002)*

Incised Channel A stream channel in which the bed has dropped and as a result, the stream is disconnected from its floodplain.

Infiltration The downward movement of water from the surface to the subsoil. The infiltration capacity is expressed in terms of inches per hour. *(1991 Storm Drainage & Surface Water Management Plan)*

Infiltration Facility	A drainage facility designed to use the hydrologic process of surface and stormwater runoff soaking into the ground, commonly referred to as percolation, to dispose of surface and stormwater runoff. *(PCC Stormwater Management & Site Development Manual, 1999)*
Instream Flow	Instream flow is the amount of water in a stream required to support or protect existing uses of fish and fish habitat. *(Glossary of Parameters, Washington State Section 303(b) Report, 9-2001)*
Intermittent Stream Channel	Streams or stream reaches that carry water consistently for part of the year and are dry during the remainder of the year. See ephemeral stream channel.
Landscape	All the natural features such as grasslands, hills, forest and water, which distinguish one part of the earth's surface from another part; usually that portion of land that the eye can comprehend in a single view, including all its natural characteristics.
Large woody debris (LWD)	Any piece of woody material generally 12 inches or larger in diameter that intrudes into a stream channel or nearby (e.g., logs, stumps or root wads) and that functions to form pools, regulate sediments, disperse stream energy, create channel complexity, stabilize channels, provide instream organic matter, and provide cover for fish.
Leachate	Percolating water which has picked up dissolved materials (typically pollutants.
LID	See Low Impact Development.
Limiting Factors	Conditions that limit the ability of habitat to fully sustain populations of salmon.
Losing Stream	A stream or reach of a stream that loses water by seepage into the ground; also known as an influent stream. *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Low Impact Development (LID)	The use of designs which incorporate low impact best management practices (BMPs) into site development with the goal of alleviating both specific and cumulative hydrologic impacts from changes in land use. *(Draft Tri-County 4(d) Rule Proposal 5-2002)*
LWD	See Large Woody Debris.
Macrobenthic Invertebrates	Small animals which spend a portion of their life cycle within the bottom substrate of a water body.

Main Stem	The principal channel of a stream to which tributaries join.
Meander Pattern	A series of sinuous curves or loops in the course of a stream that are produced as a stream swings from side to side in flowing across its floodplain.
Mitigation	Avoiding, rectifying, minimizing, reducing, compensating for or eliminating probable significant adverse impacts to a natural resource or environment. See also WAC 197-11-768. *(Summary form of definition in the Draft Tri-County 4(d) Rule Proposal 5-2002)*
NMFS	National Marine Fisheries Service.
Native	Occurring naturally in a habitat or region; not introduced by humans.
Natural Flow	Stream flow values as they would have occurred in a state of nature preceding any human influences that might alter the flow including diversions from a river or changes in land use or land cover. *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
NTU	Nephelometric Turbidity Unit; a measure of water turbidity.
Off-Channel Habitat	Ponds, oxbows, sloughs and other backwater areas with cover that provide high-quality rearing habitat for juvenile salmon and refuge during storm flows.
Open Space	A landscape which is primarily unimproved. Open space areas may include: critical areas, wooded areas, and parks, trails, privately owned natural reserves, abandoned railroad lines, utility corridors, and other vacant rights-of-way. Permanent dedications, designation, or reservation of open space for public or private use may occur in accordance with Comprehensive Plan policies. Open space may include Natural Open Space, Natural Buffer Areas, Buffers, and Screening. *(Draft Definitions for PCC Title 18, 1-2002)*
pH	A symbol for the degree of acidity or alkalinity of a solution. pH values from 0 – 7 indicate acidity and from 7 -14 indicate alkalinity. *(Websters New World Dictionary, 1984).*
Palustrine Wetlands	Nontidal wetlands that are dominated by trees, shrubs, persistent or nonpersistent emergents, mosses, or lichens body.
Peak Discharge	The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event *(1991 Storm Drainage & Surface Water Management Plan).*
Perennial Stream	A watercourse that flows throughout the year *(A Dictionary of Geography, Oxford University Press, 1997).*

Pervious — A solid surface that contains a sufficient amount of void space to allow water to infiltrate through it. *(Draft Definitions for PCC Title 18, 1-2002).*

Piezometer — A small diameter tube, pipe or well used to measure the elevation of the water table body.

Pothole — A closed drainage basin from which there is no surface water outlet. *(PC Stormwater Management & Site Development Manual, 1999)*.

Priority Habitat — A seasonal range or habitat element with which a given species has a primary association and which, if altered, may reduce the likelihood that the species will maintain or increase population over the long term. These might include areas of high relative density, breeding habitat, winter range, and movement corridors. Priority habitats might also include areas that are of limited availability or high vulnerability to alteration, such as cliffs, talus, wetlands, etc. *(Draft Definitions for PCC Title 18, 1-2002)*

Priority Species — An animal species of concern due to their population status and their sensitivity to habitat manipulation. Priority species include species of concern, monitor species, candidate species, priority game species, as well as other game and non-game species. *(Draft Definitions for PCC Title 18, 1-2002)*

Programmatic — Relating to a plan or procedure for dealing with some matter, e.g., regulations, policy guidelines, site design standards, operational policies and procedures, technical assistance, enforcement, and public outreach and educational programs.

Reach — A segment of a stream channel where the cross-section, slope and roughness of the channel are constant. Simulation of the flow in streams is done by dividing the stream channel into reaches. *(adapted from Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*

Recharge Area — An area in which there are downward components of hydraulic head in the aquifer; where infiltration moves downward into the deeper parts of an aquifer (*Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002).*

Redd — Spawning nest made by salmonid fish.

Reed Canary Grass	An invasive grass species that thrives in open, wet areas, often a nuisance plant in riparian and wetland areas.
Reference Site (Stream Geomorphology Context)	The stable morphological stream type in the system. The type may, or may not, be in a pristine state. The majority of time, it is not pristine, however, the important geomorphologic and most likely vegetative components are there to sustain a long-term stable stream type. The reference site would fall within the range of natural variability for geomorphic type and bed load transport.
Regional Stormwater Facility	Stormwater detention, retention or water quality control facility designed to manage runoff from large tracts of land (subbasins) *(PCC Stormwater Management & Site Development Manual).*
Restoration	The reestablishment of a viable wetland or critical fish or wildlife habitat area from a previously filled or degraded site *(Draft Definitions for PCC Title 18, 1-2002).*
Retention	The holding of runoff in a basin without release except by means of evaporation, infiltration or emergency bypass *(1991 Storm Drainage & Surface Water Management Plan).*
Riffles	Shallow reaches with low subcritical flow (1-4 percent gradient) in alluvial channels of finer particles that are unstable and are characterized by small hydraulic jumps over rough bed material, causing small ripples, waves, and eddies, without breaking the surface tension. Riffles are important in maintaining the water level in the pool immediately upstream of the riffle body.
Right-Of-Way (ROW)	A strip of land held in an easement or separate tract which is occupied or dedicated to be occupied by a publicly or privately dedicated street or railroad, together with property reserved for utilities, transmission lines and extensions, walkways, sidewalks, bikeways, equestrian trails, and other similar uses.
Riparian Area	"Riparian area" means land areas directly influenced by a body of water. Usually such areas have visible vegetation or physical characteristics showing this water influence. Stream sides, lake borders, and marshes are typical riparian areas. Generally refers to such areas along flowing bodies of water. The term *Littoral* is generally used to denote such areas along non-flowing bodies of water. *(Draft Definitions for PCC Title 18, 1-2002)*

Riprap A combination of large stone, cobbles and boulders used to line channels, stabilize banks, reduce runoff velocities or filter out sediment *(1991 Storm Drainage & Surface Water Management Plan).*

River Mile (RM) The distance in miles measured from its downstream terminus used for specifying the location of features or facilities along a river *(adapted from Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)* .

Road Density A measure of the quantity of roads within a given area of land, usually represented in units of miles of road per square mile of watershed area *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002).*

ROW See Right-of-Way.

Runoff Water originating from rainfall and other precipitation that si found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes and wetlands, as well as shallow ground water *(PC Stormwater Management & Site Development Manual, 1999).*

Rural Lands Lands, which are not within an urban growth area and are not designated as natural resource lands having long term commercial significance for production of agricultural products, timber, or the extraction of minerals. (*PCC 18A.10.050 and Draft Definitions for PCC Title 18, 1-2002)*

SEPA State Environmental Policy Act (RCW 43C).

Salmonids Fish of the family Salmonidae, including salmon, trout, char (salmon and steelhead stock inventory), whitefish and grayling native to Washington State.

Scour Process by which floodwaters remove soil around objects that obstructs flow, such as the foundation wall of a house, the channel of a stream, or below a culvert.

Sediment Solid material settled from suspension in a liquid *(Office of Water Programs, California State University, Sacramento, 2-2002).*

Sedimentation The process of settling and depositing of suspending matter carried by runoff; usually occurring by gravity when the velocity of the surface water is reduced below the point at which it can transport the suspended material *(Office of Water Programs, California State University, Sacramento, 2-2002).*

Sinuosity	The ratio of stream channel length (measured in the thalweg) to the down-valley distance, or is also the ratio of the valley slope to the channel slope. When measured accurately from aerial photos, channel sinuosity is also used to estimate channel slope (valley slope/sinuosity). Sometimes sinuosity is referred to as the meander of a stream.*)*
Site Development Standards	A variety of standards applied to site development that can include, among others, principles for placement of buildings on site, provision of open space, access roads, drainage facilities, lighting, parking and landscaping. *(PCC Title 19, Appendix A*)
Soil Permeability	The ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil. *(PC Stormwater Management & Site Development Manual, 1999)*
Spawning Habitat	Areas used by adult fish for laying and fertilizing eggs.
Stade	A short period of time (less than 10,000 years) characterized by climatic conditions associated with maximum glacial extent. *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Stakeholder	An individual, jurisdiction, agency, or entity with an interest in the outcome of the planning process.
Storm Drains	The enclosed conduits that transport surface and stormwater runoff toward points of discharge.(sometimes referred to as storm sewers) *(PC Stormwater Management & Site Development Manual, 1999)*
Stormflow	The portion of flow which reaches the stream shortly after a storm event. *(1991 Storm Drainage & Surface Water Management Plan)*
Stormwater	The portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels or pipes into a defined surface water channel, or a constructed facility. *(PCC Stormwater Management & Site Development Manual, 1999)*
Stormwater Management	Management of the quantity, quality and conveyance of surface water runoff from precipitation.
Stream	A channel of perennial or intermittent flowing water.
Subbasin	A drainage area which drains to a watercourse or water body named and noted on common maps and which is contained within a basin; a basin or area which is part of a larger drainage basin or area. *(Draft Tri-County 4(d) Rule Proposal 5-2002)*

Substrate	The rock or soil material present in the bottom of the stream or river, including muck, sand, gravel, boulders and bedrock. *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Surface Water	"Surface water" means an open body of water that flows or is collected on the earth's surface such as rivers, lakes, reservoirs, ponds, streams, seas, estuaries, etc., and all springs, wells, or other collectors directly influenced by surface water. *(Draft Definitions for PCC Title 18, 1-2002)*
Swale	A natural depression or wide shallow channel that temporarily stores, routes or filters runoff.*(1991 Storm Drainage & Surface Water Management Plan)*
Total Impervious Surface Area	The percentage of the surface area occupied by all impermeable surfaces. It includes both effective impervious surfaces that are connected to the surface water drainage system and the non-effective impervious surfaces that discharge to permeable surfaces where stormwater can infiltrate into the ground.
Total Nitrogen	The amount of nitrogen in water that is available for plant growth or exceeds the necessary amount. *(adapted from Glossary of Parameters, Washington State Section 303(b) Report, 9-2001)*
Total Phosphorus	Total phosphorus (in the form of phosphate) is a major source of nutrients for plant life, too much in water increases algae growth which can use up available oxygen necessary for the survival of fish and other inhabitants of fresh and marine waters. *(adapted from Glossary of Parameters, Washington State Section 303(b) Report, 9-2001)*
Total Suspended Solids (TSS)	A measure of the weight of mineral or organic solids suspended in a given volume of water; used as a measure of sedimentation or siltation and as an indicator of pollutants known to attach to solids. *(adapted from A Citizen's Guide to Understanding & Monitoring Lakes and Streams, WSDOE, 6-3-2002)*
Tri-County Endangered Species Act Response	A collaborative effort of Pierce, King and Snohomish Counties with Indian tribes, cities, businesses and environmental organizations to resolve issues surrounding recovery of depressed salmon stocks. Also known as the Tri-County Salmon Recovery effort. *(Adapted from information on the Tri-county Salmon Information Center website -* www.salmoninfo.org*)*
TSS	See Total Suspended Solids.

Turbidity	A measure of the amount of light scattered from a sample and therefore a measure of suspended solids in water. Too high of turbidity indicates blockage of sunlight needed for aquatic life and high sediment levels. *(Adapted from Glossary of Parameters, Washington State Section 303(b) Report, 9-2001and Chapter 3, A citizen's Guide to Understanding & Monitoring Lakes and Streams, 6-3-2002)*
Undercutting	The removal of material at the base of a steep slope or cliff by the erosive action of waves, running or seeping water, or windblown sand. *(Draft Definitions for PCC Title 18, 1-2002)*
Undeveloped	A property in a state generally approaching being native or natural covered with living, mature vegetation.*(Draft Tri-County 4(d) Rule Proposal 5-2002)*
Urban Growth Area	Those areas established through the designation of a boundary which separates existing and future urban areas from rural and resource areas. An urban growth area defines where developments will be directed and supported with historical and typical urban governmental services and facilities, such as storm and sanitary sewer systems, domestic water systems, street cleaning services, fire protection services, and public transit services. Urban Growth Areas are established by the Pierce County Comprehensive Plan. *(Draft Definitions for PCC Title 18, 1-2002)*
USGS (United States Geological Survey)	Agency within the federal Department of the Interior responsible for collecting and distributing stream flow data for the nation.*(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Water Body	Surface waters including rivers, streams, lakes, ponds, marine waters, estuaries, and wetlands. (*Draft Definitions for PCC Title 18, 1-2002)*
Water Resources Inventory Area (WRIA)	An administrative and planning unit in Washington State that encompasses a large river basin. *(Nisqually River Basin, Draft 2514 Technical Assessment, 6-2002)*
Watershed	The region drained by or contributing water to a stream, lake, or other body of water. *(PCC Title 19, Appendix A)*
Water Table	The upper level of groundwater or the zone of saturation for underground water. It is an irregular surface with a slope or shape determined by the quantity of ground water and the permeability of the earth material. Also referred to as *Groundwater Tabl*e. *(Shortened from Draft Definitions for PCC Title 18, 1-2002)*
WDFW	Washington State Department of Fish and Wildlife.

WDOE Washington State Department of Ecology.

WDOH Washington State Department of Health.

Wetland Areas that are inundated or saturated by surface water or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands generally do not include those artificial wetlands intentionally created from nonwetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities; or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. However, wetlands may include those artificial wetlands intentionally created from nonwetland areas created to mitigated conversion of wetlands, if permitted by Pierce County. *(RCW 36.70A.030 & PCC Title 19, Appendix A)*

WRIA See Water Resources Inventory Area.

Zoning The process by which a county or a municipality legally controls the use of property and physical configuration of development upon tracts of land within its jurisdiction. Zoning is an exercise of the police power and as such must be enacted for the protection of public health, safety and welfare. (*PCC Title 19, Appendix A)*